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A Total Polyphenol Content of Mate (*Ilex paraguariensis*) and Other Plants-derived Beverages

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Abstract

The total polyphenol content (TPC) of three *maté* (*Ilex paraguariensis* St. Hil.) beverages under typical consumer conditions in Argentina: Hot *Maté*, Cold *Maté* and *Maté* tea-bag, were determined.TPC was measured by the Folin-Ciocalteu method and expressed as gallic and chlorogenic acid equivalents (GAE and CAE, respectively). In Hot *Maté*, the intake would be 5.15 ± 0.55 g CAE /500 mL and 2.9 ±0.4 g GAE/500 mL; in Cold *Maté*, the intake would be 1.9 ± 0.4 g CAE /500 mL and 1.1 ± 0.2 g GAE/500 mL; one cup of *Maté* Tea-bag infusion (200 mL) contains between 0.55 ± 0.05 g CAE and 0.295 ± 0.015 g GAE. Comparison of the TPC of several beverages provided evidence that beverages of *maté* are rich sources of antioxidant phenolics. Among several ways of consumption of *maté*, the Hot *Maté* provides the highest intake of total polyphenols.

Keywords: antioxidant, Folin-Ciocalteu, *Ilex paraguariensis*, *maté* beverages, polyphenols

1. Introduction

Yerba maté (*Ilex paraguariensis* St. Hil.) is a tree that grows in the central region of the *MERCOSUR* (Common Southern Market) countries (Paraguay, Brazil, Argentina and Uruguay); its leaves and twigs are processed to obtain two final products: elaborated *maté* and *maté* tea-bags. Elaborated *maté* is obtained through an industrial process that includes the following steps: heat treatment, drying, grinding and seasoning (Scipioni et al., 2010).

Maté products are consumed in the MERCOSUR region. In recent years, the USA and some countries in Europe and in the Middle East have begun to use *maté* infusion due to its antioxidant capacity (Heck et al., 2008). The *maté* is recognized worldwide for its nutritional and medicinal value being included in several nationals food codes such as the Argentine Food Code, Latin-American Food Code and Pharmacopoeias such as Martindale, British Herbal Pharmacopoeia and German Commission E Monographs (Anesini et al., 2006).

Several studies on *maté* have reported the presence of xanthines such as caffeine and theobromine, saponines, and several phenolic compounds, mainly chlorogenic acids and dicaffeoylquinic acid derivatives (Bravo et al., 2007; Dutra et al., 2010; González de Mejia et al., 2005; Heck et al., 2008; Jaiswal et al., 2010; Markowicz Bastos et al., 2007). It has also been reported that *maté* extracts have an *in vitro* antioxidant capacity (AOC) which is due to the presence of chlorogenic acids and dicaffeoylquinic acid derivatives that have an antioxidant capacity equal to or higher than that of ascorbic acid and vitamin E (Bravo et al., 2007; Chandra & Gonzalez de Mejia, 2004). Dudonné et al. (2009) ranged aqueous extracts of mate in the fifth place of plants, among 30, with higher antioxidant activity.

Chandra and Gonzalez de Mejía (2004) reported a total polyphenol content (TPC) in the range from 9.0 to 17.6 g gallic acid equivalent (GAE) and from 23.6 to 49.0 chlorogenic acid equivalent (CAE) per 100 g of dry mass (dm) for *maté* beverages prepared as decoctions of nearly 3 g of mate leaves in 250 mL of boiling water.

Three different types of beverages are consumed. The Hot *Maté* is consumed in a special preparation, where

30 - 50 g of elaborated *maté* are placed in a gourd and fractions of approximately 30 mL of hot water (at 70 - 85 °C) are poured over solid repeatedly. The water is removed with a device similar to a straw, called ‘‘*bombilla*,” that has a filter at one end (Scipioni et al., 2010). The Cold *Maté*, known as “*tereré*” is consumed in the same way that Hot *maté* but using cold water (at 5-8 °C), and *Maté* Tea-bag, which is known as “*maté cocido*” and is prepared with the leaves only and brewed as any other herbal tea-bag.

Reports about TPC present in the three *maté* beverages mentioned above were not found in the literature. Their content will provide us an idea of the real intake of polyphenols by the consuming of *maté* beverages. The aim of the present research was to determine the TPC, as well as other physicochemical properties of these three *maté* beverages, and compare them with the TPC of other common beverages with well-known antioxidant properties such as red wine and the two major commercial tea products: green and black tea (*Camellia sinensis*) infusions.

2. Materials and Methods

2.1 Reagents

In total polyphenol content (TPC) determination, Folin-Ciocalteu’s phenol reagent (Fluka, Argentina), chlorogenic acid (MP Biomedicals, Argentina), gallic acid (MP Biomedicals, Argentina), *anhydrous* sodium carbonate (99% purity, Anedra, Argentina), methanol (Merck, HPLC grade, Argentina) and ethanol 96º, were used. In caffeine content determination, caffeine (Sigma Ultra, Argentina) and methanol (Merck, HPLC grade, Argentina) were used.

2.2 Materials

Samples of elaborated *maté*, *maté* tea-bag, red wine, and green and black tea (in tea-bags) were randomly purchased in local markets in Posadas, Misiones, Argentina. Ten different brands of elaborated *maté*, purchased in 1 kg paper bags, and five different brands of *maté* tea, purchased in boxes of 25 tea-bags each, were analysed. The contents of each package of elaborated *maté* were mixed by successive quartering before sampling. Each tea-bag used was randomly sampled. Five Argentinean brands of red wine (a Cabernet Sauvignon, a Malbec, a Syrah and two generics), six Argentinean brands of black tea and three Argentinean brands of green tea were analysed.

2.3 Extractions

Extractions were obtained simulating the way and proportions in which the beverages are usually prepared and consumed: for the Hot *Maté*, a glass recipient (diameter = 50 mm and height = 110 mm) (Figure 1) was filled with 50 ± 0.1 g of elaborated *maté* and a plastic straw was inserted in the material *(*Scipioni et al., 2010).

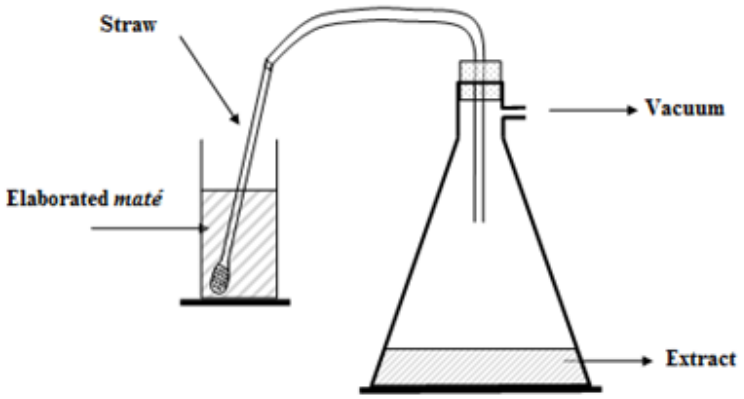

Figure 1. Device simulating the *maté* consumption

The submerged end of the straw had holes smaller than 0.8 mm that allowed the brewed liquid in, but blocked the solid powder. The straw was connected by a silicon hose to a *kitasato* flask, which was, in turn, connected to a *vacuum* pump. Then, approximately 20 mL of distilled water at 70 ºC was added, allowing the water to be absorbed into the *maté* for 20 s. *Vacuum* was then applied for 20 s and when the *vacuum* stopped, the aliquot

of hot water was added again. This process was repeated until the recovered volume in the *kitasato* flask reached 500 mL. The preparation of Cold *Maté* was equal to that of the Hot *Maté*, except for the water temperature, which was 5 °C. *Maté* Tea, black tea and green tea were prepared by brewing one commercial tea bag (net weight = 2-3 g) in distilled boiling water, allowing it to brew for 5 min. After this time, tea bags were removed and the final volume readjusted. Considering the tea bag charge varies considerably, in order to systematize the brewing procedure, the volume of boiling water used was according to a water/solid ratio of 67/1.

As a control, the extraction method described by the international standard ISO 14502 was used for elaborated *maté* samples. This extraction method was also used in *maté* leaves and *mat*é and twigs. Briefly, 0.200 ± 0.001 g of each sample was weighed in an extraction tube, and 5 mL of methanol (70 % v/v) at 70 °C was added. The extract was mixed and heated at 70 °C on a vortex for 10 min. After cooling at room temperature, the extract was centrifuged for 10 min. The supernatant was decanted in a graduated tube. The extraction step was repeated twice. Both extracts were pooled and the volume adjusted to 10 mL with cold methanol (70 % v/v).

2.4 Moisture Content

Water moisture was determined by the gravimetric method described by the standards IRAM 20503 (Argentinean standard, similar to standard ISO 1573 for tea samples). Briefly, around 2.500 ± 0.001 g of sample was dried for 6 h at 103 ± 2 ºC in an oven. Results were expressed as mass percentage (g % wet matter).

2.5 Aqueous Extract

The aqueous extract was obtained with boiling water under reflux under the conditions specified in the Argentinean standard IRAM 20510. The insoluble residue was then dried and weighed. Results were expressed as mass percentage (g per 100 g of dry matter; or g % dm).

2.6 Total Soluble Solids

An aliquot of 50 mL of each extract was fast paper-filtered and then 10 mL was transferred into a tared beaker and evaporated to dryness. The residue was dried for 16 h at 103 ± 2 ºC in an oven. Determinations were carried out in triplicate. Results were expressed as mass percentage (g per 100 g of dry matter; or g % dm).

2.7 Percentage of Each Fraction

The percentage of leaves, twigs and impurities of mate samples were determined according to the Argentinean standard IRAM 20514. Each fraction was separated by sieving for 20 min using an electronic sieve. Determinations were carried out in triplicate. Results were expressed as mass percentage (g %).

2.8 Caffeine Content

Caffeine was determined using an HPLC technique specified in the standard IRAM 20512. A C18 column (Ultrasphere; 250 mm × 4.6 mm, Beckman, USA) with a particle diameter of 5 µm, a mobile phase of methanol:water (30:70 v/v) with a flux of 1.1 mL/min were used, at 280 nm using a spectrophotometer UV/Vis (Waters, M481, spectrum bandwidth: 5 nm). Determinations were carried out in duplicate. Results were expressed as mass percentage (g % dm).

2.9 Total Polyphenol Content

The total polyphenol content (TPC) was determined by a spectrophotometric technique, using a spectrophotometer UV/Vis (Spectrum SP-2102, photometric accuracy 0.3 %T, spectrum bandwidth: 2 nm) according to the method described in the international standard ISO 14502. The content was expressed as gallic acid equivalents and chlorogenic acid equivalents in mass percentage of dry matter (GAE; CAE; g % dm). One milliliter of the diluted sample extract (or 1 mL of pure wine) was transferred in duplicate to separate tubes containing 5.0 mL of water diluted Folin-Ciocalteu's reagent (10 % v/v). Then, 4.0 mL of a sodium carbonate solution (7.5 % w/v) was added. The tubes were then allowed to stand at room temperature for 60 min before absorbance was measured at 765 nm against distilled water. The concentration of polyphenols in samples was derived from a standard curve of chlorogenic and gallic acid ranging from 0 to 60 µg/mL (R^2 = 0.997 and R^2 = 0.998 respectively). The total polyphenol concentration in the original extracts (TPCo) was expressed as CAE and GAE in µg/mL of the original extract. Determinations were carried out in duplicate.

2.10 Statistics

2.10.1 Experiment Design

The experiment was organized using a randomized complete block design, with each type of beverage as

treatments (Hot *Maté*, Cold *Maté* and control extraction) and brands as blocks.

2.10.2 Statistical Analysis

Analysis of variance (ANOVA) was used. For comparing the TPC of Hot and Cold mate and control extractions, the Tukey`s least significant difference was used. Correlation analysis was performed with the Pearson`s Correlation technique. All the comparisons were made at a 5 % level of significance. Data are expressed as mean ± standard error of two determinations per sample. All the statistical analysis were performed using Statgraphics Centurion XVI *Académico*.

3. Results and Discussion

3.1 Results of Physicochemical Analysis

In accordance with González de Mejía et al. (2005), the TPC of *maté* resulted higher when it is expressed as chlorogenic acid equivalents than when it is expressed as gallic acid equivalents. Due to the fact that gallic acid is not relevant to *maté* (González de Mejia et al., 2005), it is more appropriate to express TPC as chlorogenic acid equivalents. In the case of tea, gallic acid is not relevant either, but in comparison to other standards which may be more relevant, (*e.g.*, catechins such as EGCG), gallic acid is more freely available and more stable than the other standards.

The TPC in the leaf fraction resulted significantly higher than the TPC of the twig fraction ($p \leq 0.012$).The results found in this work were 22.2 ± 0.1 g CAE % dm in the leaf extraction and 14.1 ± 1.2 g CAE % dm in the twig extraction; these values resulted higher than the values reported by Holovatty (2007) (17.3 ± 0.3 and 6.6 ± 0.1 g CAE % dm in the leaves and twigs respectively). These differences may be attributed to many reasons, such as the lack of standardization in the extraction and in the Folin-Ciocalteu application.

The *aqueous* extract of the elaborated *maté* and the *maté* tea-bags were 36.30 ± 2.24 g % dm and 40.86 ± 1.22 g % dm respectively. The soluble solids in the three *maté* beverages resulted 22.81 ± 3.620, 11.08 ± 2.148 and 37.7 ± 0.418 g % dm for the Hot *Mate*, Cold *Mate* and *Mate* Tea-bag respectively.

The caffeine content of the elaborated *maté* and the *maté* tea-bags resulted 1.21 ± 0.08 g % dm and 1.32 ± 0.21 g % dm respectively.

The TPC of the different brands and extraction procedures are presented in Table 1. The resulting ANOVA for TPC in Hot *Maté*, Cold *Maté* and Control extraction is presented in Table 2. The extraction procedure affected the TPC ($p \leq 0.0001$). The TPC in the different *maté* extracts decreased in the order: *Maté*-Tea, Control extraction, Hot *Maté,* Cold *Maté*. Many factors, such as the extraction temperature (Wettasinghe and Shahidi, 1999), the solvent polarity (Turkmen et al., 2006) and the solid-to-solvent ratio (Cacace and Mazza, 2003), may significantly influence the extraction efficacy of polyphenols. *Maté* tea-bag is produced almost exclusively from leaves, whereas elaborated *maté* is produced from leaves and twigs (usually in a 65/35 proportion. The avegare percentage of each fraction of *maté* resulted: 76.7 ± 2.22 % for leaves, 22.7 ± 2.42 % for twigs and 0.60 ± 0.41 % for impurities.

Is important to clarify that in the case of Hot and Cold *Maté*, the infusion time between additions of water and consumption is comparatively short, so surely none of these beverages ensures the total extraction of maté polyphenols compounds. Currently no standard is available for total extraction of maté polyphenols thus we reffered the avegare TPC of the beverages simulated to the total soluble solids. It is well known total soluble solids represent the amounts of solid extracted in specific extraction conditions

The average TPC of the Hot *Maté* and the Cold *Maté* are presented in Table 3, they represented the 48 % and 36 % of the total soluble solids respectively. In *Maté* Tea-bag the average TPC was 19.25 ± 0.37 g CAE % dm which represented the 50 % of the total soluble solids whereas the respective TPC expressed as GAE resulted 10.52 ± 0.25 g GAE % dm. The above result are closely to the results reported by González de Mejia et al. (2005) and Bravo et al. (2007) for mate decoctions. In those reports the TPC ranged 23.6 - 49.0 CAE % dm and 9.0 - 17.6 g GAE % dm (González de Mejia et al., 2005) and 9.07 - 9.90 g GAE % dm (Bravo et al., 2007).

A previuos report based in polyphenols extraction mixtures (at 85 ºC) suggests that polyphenols in fresh leaves and twigs of maté are different (Pagliosa et al., 2010). In this report the better extraction from leaves was found when water was used and in the case of twigs when a methanol/water mixture (80/20 in volume) was used.

Table 1. Total polyphenol content of different brands and extraction procedures

	Hot Mate	***Cold Mate***	***Mate tea-bag***	***Control***
Brand*	TPC-CAE[a] (g CAE % dm)	TPC-CAE (g CAE % dm)	TPC-CAE (g CAE % dm)	TPC-CAE (g CAE % dm)
1	11.72 ± 0.12	4.18 ± 0.10	---	19.32 ± 0.41
2	10.44 ± 0.01	3.24 ± 0.06	---	15.84 ± 0.29
3	9.58 ± 0.05	3.57 ± 0.06	20.10 ± 0.20	16.50 ± 0.14
4	12.94 ± 0.16	4.11 ± 0.10	---	17.10 ± 0.63
5	11.06 ± 0.01	3.89 ± 0.08	---	17.45 ± 0.13
6	10.74 ± 0.26	2.56 ± 0.04	18.14 ± 0.12	16.87 ± 0.37
7	11.77 ± 0.04	5.49 ± 0.02	18.61 ± 0.15	17.31 ± 0.08
8	10.85 ± 0.06	5.19 ± 0.07	19.76 ± 0.25	18.24 ± 0.10
9	9.16 ± 0.10	4.25 ± 0.03	19.66 ± 0.28	17.45 ± 0.05
10	11.74 ± 0.03	3.83 ± 0.08	---	17.91 ± 0.07
Brand*	TPC-GAE[b] (g GAE % dm)	TPC-GAE (g GAE % dm)	TPC-GAE (g GAE % dm)	TPC-GAE (g GAE % dm)
1	6.91± 0.07	2.51 ± 0.06	---	10.56 ± 0.22
2	6.19 ± 0.01	1.97 ± 0.03	---	8.66 ± 0.16
3	5.21 ± 0.03	1.95 ± 0.03	11.00 ± 0.11	9.02 ± 0.08
4	7.60 ± 0.09	2.47 ± 0.06	---	9.35 ± 0.35
5	6.54 ± 0.01	2.34 ± 0.05	---	9.56 ± 0.07
6	5.85 ± 0.14	1.45 ± 0.02	9.91 ± 0.07	9.22 ± 0.20
7	6.41 ± 0.02	3.00 ± 0.01	10.17 ± 0.08	9.46 ± 0.05
8	5.91 ± 0.04	2.83 ± 0.04	10.80 ± 0.13	9.97 ± 0.06
9	4.98 ± 0.06	2.38 ± 0.02	10.74 ± 0.15	9.54 ± 0.03
10	6.92 ± 0.02	2.31 ± 0.05	---	9.79 ± 0.04

* Data are expressed as mean ± standard error of two determinations per sample. [a]TPC-CAE: Total polyphenol content expressed as chlorogenic acid equivalents; [b]TPC-GAE: Total polyphenol content expressed as gallic acid equivalents.

Table 2. ANOVA analysis for total polyphenol content

		TPC-CAE		**TPC-GAE**	
Source of variation	f.d.	F	p-value	F	p-value
		128.36	<0.0001	94.74	<0.0001
Model	11	694.67	<0.0001	510.27	<0.0001
Extraction Procedure	2	2.51	0.0461	2.4	0.0545
Brand	9				
Error	18				
Total	29				

f.d.: degrees of freedom; TPC-CAE: Total polyphenol content expressed in mass percentage as chlorogenic acid equivalents; TPC-GAE: Total polyphenol content expressed in mass percentage as gallic acid equivalents.

Turkmen et al. (2006), studied the effect of water and different organic solvents (acetone, ethanol and methanol at 50%, 80 % and 100% v/v) in the extraction of polyphenols and on the antioxidant capacity of several vegetables including maté. In the case of mate leaves all extracts prepared with 50% solvents showed the highest levels of polyphenols and the lowest amounts of polyphenols were obtained with 100% acetone and 100% ethanol. They concluded that the solvent polarity increases the polyphenols extraction.

The results of Tukey´s Test significance for TPC from Hot *Maté*, Cold *Maté* and Control extraction are shown in Table 3.

Table 3. Results of Tukey´s Test significance for TPC

	Mean values*	
	TPC-CAE	**TPC-GAE**
	(g % dm)	(g % dm)
Hot *Mate*	11.00[a]	6.25[a]
Cold *Mate*	4.03[b]	2.32[b]
Control	17.4[c]	9.51[c]
$LSD_{TPC-CAE}$: 0.9155	$Error_{TPC-CAE}$: 0.6435	$f.d._{TPC-CAE}$: 18 n:10
$LSD_{TPC-GAE}$: 0.2542	$Error_{TPC-GAE}$: 0.5753	$f.d._{TPC-GAE}$: 18 n: 10

*Values bearing different letters are significantly different at $p \leq 0.05$. f.d.: degrees of freedom; TPC-CAE: Total polyphenol content expressed in mass percentage as chlorogenic acid equivalents; TPC-GAE: Total polyphenol content expressed in mass percentage as gallic acid equivalents.

The TPC correlated with the soluble solids in the case of Cold *Maté* ($r_{Pearson} = 0.96$, $p \leq 1.5 \times 10^{-5}$) and Hot *Maté* ($r_{Pearson} = 0.85$, $p < 0.01$). TPC also correlated with the *aqueous* extract from *maté* in the case of Hot *Maté*, but did not correlate with the leaf percentage, probably because it is very homogeneous within all brands.

3.2 Estimation of the Total Polyphenol Intake from Maté Beverages

By drinking 500 mL (volume usually consumed) of Hot *Maté* and Cold *Maté,* the total polyphenol intake (TPI) is 5.17 ± 0.53 g CAE or 2.94 ± 0.38 g GAE; and 1.89 ± 0.40 g CAE or 1.09 ± 0.21 g GAE respectively. These high differences between Hot and Cold Maté are probably due to the temperature used in the extraction.

For a cup (200 mL) of *Maté* Tea-bag, the TPI is 0.54 ± 0.02 g CAE or 0.30 ± 0.01 g GAE. In the case of *Maté* tea-bag, the water to solid ratio employed is 6.6 times higher than in Hot and Cold *Maté*.

The habit of drinking Hot *Maté* and Cold *Maté* implies the daily consumption of large volumes of these beverages: according to Castellsague et al. (2000) the heavy drinkers consume more than 1.5 L/day, while light drinkers consume less than 0.5 L/day.

The polyphenol compounds may be classified into different groups as a function of the number of phenol rings that they contain and of the structural elements that bind these rings to one another. Distinctions are thus made between the phenolic acids, flavonoids, stilbenes and lignans. In addition to this diversity, polyphenols may be associated with various carbohydrates, organic acids and lipids and with one another. As an example, chlorogenic acid is a caffeic acid ester linked to quinic acid. The structural diversity of polyphenols makes the estimation of their content in food difficult. Polyphenols concentrations in food vary according to numerous genetic, environmental and technologic factors.

A major source of polyphenols is beverages (as *maté* beverages, red wine, coffee and tea). Each one of these beverages contains different complex mixtures of polyphenols. Cultural and dietary habit dictates which forms of polyphenols are taken up.

In *maté* extracts, monocaffeoyl quinic isomers and dicaffeoyl quinic isomers had been reported. The main monocaffeoyl quinic isomers reported are chlorogenic acid (5-*o*-caffeoyl quinic acid), neochlorogenic acid (3-*o*-caffeoyl quinic acid) and cryptochlorogenic acid (4-*o*-caffeoyl quinic acid). The main dicaffeoyl-quinic isomers are 3,4-dicaffeoylquinic acid, 3,5-dicaffeoylquinic acid and 4,5-dicaffeoylquinic acid. According to Bravo et al. (2007), together they account for over 90 % of the TPC in *maté* extracts, representing close of

10% of *maté* dry weight (Filip et al., 2001). Rhamnoglucose derivatives of quercetin (*e.g.* rutin) and kaempferol had been reported as the major flavonoids, accounting together the 90% of the flavonols present in *maté* extracts (Bravo et al., 2007).

The phenolic compounds in red wine are represented by flavonoids as anthocyanins (mainly malvidin-3glucoside and cyanidin), flavonols (mainly catechin and epicatechin) and flavonols (mainly quercetin); and nonflavonoids as stilbenes (mainly resveratrol) and some phenolic acids (gallic acid and caffeic acid) (Rice-Evans et al., 1996).

The polyphenol compounds in green tea are represented by the free-forms of flavan-3-ols (mainly (+)-catechin, (-)-epicatechin and (-)-epigallocatechin) and their galloylated esters (mainly, (-)-epigallocatechin gallate and (-)-epicatechin gallate)(Salah et al., 1995). During green tea production, the catechins remain relatively intact during the process. This is because the enzymes, which can catalyze their oxidative polymerization, are deactivated by heat treatment soon after plucking. Black tea production, on the other hand, involves a leaf disruption step to promote the enzymatic oxidation of the flavanols (catechins) present in the fresh green leaf to produce polymeric flavonoids (theaflavins and thearubigins) (Astill et al., 2001). Thus, the prepared green teas contain substantially higher levels of catechins than prepared black teas (Astill et al., 2001). The flavonoids dominate the composition of the brew solids in tea (25 % on total soluble solids) and constitute nearly 86% of the TPC (Lakenbrink et al., 2000).

To facilitate comparison, the total polyphenol concentrations (TPCo) in several beverages tested are expressed as mg GAE per 100 mL of beverage (see Table 4). In Table 4, the great variation (expressed as standard error) is justified by the fact that the TPC of several different varieties of samples was/were averaged; e.g. five red wine varieties, ten brands of elaborated maté (industrialized by differents drying methods).

Table 4. The total polyphenol concentration in several beverages

Beverage	**TPCo*** (mg GAE/100 mL)
Hot *Mate*	586±34
Cold *Mate*	220±74
Green Tea infusion	217 ±14
Red wine	198 ±33
Mate Tea infusion	150 ±42
Black Tea infusion	147 ±28

* Data are expressed as mean ± standard error of two determinations per sample. TPCo: Total polyphenol concentration; GAE: gallic acid equivalents.

The average value for the analysed red wines was close to 2 g GAE/L and was within the ranges reported for this beverage (1.96 g GAE/L, Bravo et al., 2007; 1-4 g/L, Dreosti et al., 2000; 1.85 g GAE/L, Paixão et al., 2007).

In black tea and green tea, the TPCo was higher than the concentration previously reported for these infusions (Table 5) (nearly 1.1-1.8 and 1.8-6.2 times respectively). These differences may be justified by the fact that the TPC of the tea infusions are influenced by variety, growing environment, manufacturing conditions and finally the preparation method (different brew times and temperatures, amounts of tea and water used, amount of agitation) (Astill et al., 2001). At brew times up to 2 min, extraction of total phenolics is relatively inefficient (Lakenbrink et al., 2000).

Table 5. Summary of some representative publications of the TPC in tea and mate tea

	TPC (mg GAE/100 mL)	**WSR** (mL/g)	**Brew Time** (min)	**References**
Green tea	116.22±1.07	100/1	3	BRAVO et al. (2007)
(tea-bag)	43.3-82.5	100/1 to 114/1	3	ASTILL et al. (2001)
Black tea	93.62±2.20	100/1	3	BRAVO et al. (2007)
(tea-bag)	80-130	75/1 to 100/1	3	ASTILL et al. (2001)
Tea* (loose leaves)	35.2	125/1	**	ACTIS-GORETTA et al. (2002)
Maté tea (loose leaves)			**	ACTIS-GORETTA et al. (2002)

* Not specify green or black. ** Not specify.

4. Conclusions

The comparison of the total polyphenol content of several beverages provided evidence that *maté* beverages are rich sources of antioxidant phenolics. Among the three ways of consumption of *maté*, the Hot *Maté* provides the highest intake of total polyphenols because of several reasons: it is consumed in large volumes (around 500 mL), is prepared with more elaborated maté (50 g) than the *Maté* tea-bag (3 g) and the temperature of the beverage is higher than in Cold *Maté.*

Among the three maté beverages, the *Maté* tea-bag beverage exhibited the highest extraction efficiency because the water to solid ratio employed was 6.6 times higher than in Hot and Cold *Maté*.

During the mate beverage simmulations, the behavior of the total soluble solids resulted similar to the total polyphenols content.

We suggest including the total polyphenol content in the Nutrition Facts of *maté* products as a differential attribute that surely will promote the international market.

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