CLOSING REMARKS- INYM TRAINING SESSION

The Chemistry of *Mate*

Yerba Mate bioactive components and nutrients and their traditional ways of consumption

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Nutritional Properties

Nutrition is a scientific discipline that covers the integrated study of nutrients and their interactions with people's organisms. It studies the functions, deficiencies, and nutrient excesses and their relationship to our health by calculating the nutritional requirements or adequate quantities to achieve optimal health.

Nutrients are chemical compounds present in food that contribute to satisfizo the body´s need for energy and matter. They can be classified into organic and inorganic according to their chemical properties. Organic nutrients such as carbohydrates, proteins, and lipids are present in structure-forming and energy-transforming processes. Vitamins belong to this group and are essential for both processes and neither provide energy nor are used as structural units. They are necessary in small quantities for adequate growth, development, and homeostasis maintenance, or balance of the organism's internal environment. Water and minerals are inorganic nutrients that act as metabolism cofactors or regulators and serve structural functions.

Processed *yerba mate* is a key part of the basic food basket in Argentina, traditionally consumed in three basic forms: hot mate or just *mate*, cold *mate* or *tereré* and *mate* tea or *mate cocido*.

Mate is an infusion prepared by placing a variable amount of *yerba mate* in a container (between 25 and 50 g, depending on the size of the container). Hot water is systematically poured into the container (usually between 70 and 95 °C depending on the consumer's preference) and sipped through a *bombilla*. *Tereré* is consumed similarly but cold water (5/8°C) is poured instead. *Mate cocido* or *mate tea* is prepared by infusing *yerba mate* with boiling water, similar to tea. The *yerba mate* used for this preparation is sometimes grinded and contained in a bag or simply processed *yerba mate* can be used instead.

There are few reports on the *yerba mate* nutritional composition. Schmalko et al. (1995), researchers from the *Universidad Nacional de Misiones* (UNaM), studied the composition of certain nutrients in processed *yerba mate* (Table 1). This table shows the values of protein, sugars, vitamins, and minerals identified in the product. Like any other plant tissue, *I. paraguariensis* leaves and stems contain a chemical complex including carbohydrates, proteins, and lipids, together with minerals, vitamins, and a variety of bioactive compounds. The results yielded that *yerba mate* contains large amounts of certain minerals, including magnesium, iron, calcium, and potassium.

Table 1. Nutrients present in processed *yerba mate* and its infusions (mate tea, hot *mate,* and cold *mate)*

Nutrient contents				
	Processed *yerba mate*, (Schmalko et al. 1995)	**Infusions (Ramallo et al., 1998)**		
Component		***Mate* tea**	**Hot *mate***	**Cold *mate***
Proteins(g/100g)	10.1	3.69	2.14	1.24
Sugars (g/100g)				
Glucose	0.5	0.54	0.59	0.15
Sucrose	3.9	2.97	2.77	1.19
Minerals (mg/100g)				
Phosphorus	280	60.5	45.89	21.27
Potassium	1.180	99.64	100.59	41.63
Sodium	18	27.54	14.04	11.07
Iron	28	2.54	2.22	1.10
Calcium	900	107.25	80.94	43.90
Magnesium	640	86.96	58.58	33.17
Vitamins (mg/100 g)				
Ascorbic acid (C)	10.82	4.89	5.11	2.35
Pyridoxine (B_6)	4.35	0.54	0.94	n.d
Riboflavin(B_2)	2.35	-	-	-
Thiamine (B_1)	19.82	1.59	1.48	0.15
Niacinamide	9.68	4.38	1.27	
n.d (not detected)				n.d

Another study, carried out by Ramallo et.al., (1998) established the existence of certain nutrients (vitamins, minerals, glucose, sucrose, and proteins) in *yerba mate* aqueous extracts obtained simulating the way in which these beverages are usually prepared and consumed from the three traditional consumption forms (hot *mate, cold mate or tereré* and *mate* tea) (Table 1). The researchers observed that infusions prepared with tea bags (*mate* tea) or in hot *yerba mate* infusions (*mate*) had a higher content of the studied nutrients.

In a study carried out between 2010 and 2014 at the *Universidad Nacional de Misiones* (UNaM), the nutritional composition of hot infusions prepared with yerba mate from Argentina was evaluated. The infusions were prepared by using a device that recreates the real procedure of drinking mate. Table 2 presents the average nutritional composition of 500mL of hot *mate* obtained after analyzing 30 infusions prepared with *yerba mate* from different trademarks. To prepare mate, 50 g of *yerba mate* and water at 70°C were used, following the procedure described by Ramallo *et.al* (1998). It is worth noting that the results yielded in the above-mentioned research are similar to those obtained by another research group from the *Universidad Nacional del Nordeste* (Maiocchi *et.al*, 2016 and Maiocchi *et.al.*, 2017)

Table 2. Nutrient content of hot *yerba mate* infusions (500mL) and the average of the Recommended Daily Intake (RDI)

Component	Amount	RDI % reached	RDI*
Energy Value (kcal)	43.4	2.2	2000
Carbohydrates (g)	9.6	3.2	300
Sugar (g)	2.9	--	--
Proteins (g)	1.0	1.3	75
Total Fats (g)	0.0	0	55
Saturated Fats (g)	0.0	0	22
Trans Fat (g)	0.0	--	--
Dietary Fiber (g)	0.5	2	25
Caffeine (g)	0.4	--	--
Sodium (mg)	16.8	0.7	2400
Iron-Man (mg)	1.5	13.6	11
Iron -Woman (mg)	1.5	6.2	24
Magnesium (mg)	65.1	20.3	320
Calcium (mg)	51.0	5.1	1000
Phosphorus (mg)	22.0	3.1	700
Vitamin C (mg)	2.8	3.1	90
Thiamine (mg)	0.9	72.3	1.2
Niacin(mg)	1.6	10.1	16
Pyridoxine (mg)	0.5	37.2	1.3
* RDI for a healthy adult with an energy requirement of 2,000 kcal/day			

As it may be noticed, the caloric contribution of the infusions is low and it is completely associated with its carbohydrate content (9.6 g), as protein contribution is scarce (1.0g) and the contributions of lipids is zero.

Moreover, infusions that are prepared with *yerba mate* have a low sodium contribution (16.8 mg). As regards vitamins, Thiamine (B1) and Pyridoxine (B6) cover 72.3% and 37.2% of the RDI for both, adult men and women, between the age ranges of 18 to 50 years old, respectively. . Concerning iron, a 500mL intake of the infusion covers an average of 13.5% of the RDI for adult men and 6.2% of the required daily intake recommended for fertile women. In both cases, the results were established taking into consideration a medium bioavailability diet. Magnesium contribution to a daily diet yielded an average of 20.3% of the RDI for the same population. As regards magnesium and iron, their biodisponibility by consuming infusions prepared with *yerba mate* was studied by Sánchez Boado *et.al*, (2018). In both cases, low absorption percentages were shown making iron and magnesium contribution not

significant.The low contribution of mineral micronutrients is largely due to the effect of polyphenols that are present in *yerba mate* infusions, which retain minerals avoiding their absorption.

Another relevant issue is related to health organizations' dietary guidelines worldwide. These suggest a daily water intake of 8 glasses which is equivalent to two litres approximately. It is estimated that about 70% to 80% of the required water intake is fulfilled through drinks and the remaining 20% to 30 % is obtained from food. Water should be the most consumed liquid during the day, however, infusions such as mate are an important contribution to complement the recommended water intake.

Bioactive compounds and functional properties

In human nutrition, the term bioactive compound applies to chemical substances present in foods that affect the physiological mechanisms of individuals, thereby producing health and well-being benefits, or reducing the risk of certain diseases. Many of the *yerba mate* pharmacological properties have been attributed to its high content of bioactive compounds. *I. paraguariensis* leaves have three main bioactive substance groups in their composition, namely: a) polyphenols, b) triterpene saponins, and c) methylxanthines.

Polyphenols are heterogeneous molecule groups formed by a benzene ring attached to one or more hydroxyl groups, ranging from simple phenolic molecules to highly polymerized compounds. They are vegetable secondary metabolites that have protective functions against herbivorous organisms and phytopathogens, and UV effects. Polyphenolic compounds are included in the human diet through fruit and vegetable consumption and drinks such as wine, and infusions like tea, coffee, and *yerba mate.*

Polyphenols are the most important bioactive compounds found in *I.paraguariensis* leaves and up to the present day, there are records in the literature of more than fifty of these compounds in *yerba mate,* being chlorogenic acids, specifically, caffeoyl derivatives and certain flavonoids the most abundant.

About 10% of the dry weight of *I. paraguariensis* leaves consists of the caffeoyl derivatives 5-caffeoylquinic acid (also called chlorogenic acid), 3.5-dicaffeoylquinic, 4.5-dicaffeoylquinic, and 3.4-caffeoylquinic acids; traces of caffeic acid and the flavonoids rutin, quercetin, and kaempferol. It is noteworthy that flavonoids average about 5% of the total of phenolic compounds present in *yerba mate* extracts (Jaiswal *et.al*, 2010; Peres *et.al*., 2013).

Polyphenol content in *yerba mate* is closely related to its antioxidant power. These compounds are strong reducing agents capable of protecting the body against oxidative stress, which is associated with a reduced risk of suffering certain degenerative diseases or chronic inflammatory pathologies. Polyphenol compound's antioxidant action mechanism seems to be related to its capacity to chelate metals, inhibit enzymes generating reactive oxygen species, inhibit lipoxygenase and cyclooxygenase proinflammatory enzymes, and also capture and neutralize free radicals. Polyphenols inhibit or delay other molecules' oxidation by a process of free radicals collection and their propagation reaction, aiding in the saving of the body's antioxidant defenses (Puangraphant *et. al;*2011 b: Sánchez Boado *et.al*., 2013) In addition, recently published studies account for the prebiotic effect of these compounds. (de Vasconcellos *et.al.*, 2022)

Infusions prepared with *yerba mate* are an important polyphenol source. It has been proved that *mate* has a polyphenol content of 586 ± 34 mg GAE (gallic acid equivalent) / 100 mL This value is much higher than the polyphenol content of other beverages commonly consumed and recognized as a source of such compounds. Thus, green tea has a total polyphenol content of 217 ± 14 mg GAE/100 mL, 100 mL of red wine contains 198 ± 33 mg GAE of polyphenols, and thea black tea has 147 ± 28 mg GAE/100 mL of polyphenols. In addition to this, the average polyphenol content in *tereré* was determined, and a value of 220 ± 74 mg GAE/100 mL was observed, comparable with the contribution of green tea. Besides, it was observed that the total polyphenol content in *mate* tea was 150 ± 42 mg GAE/100 mL, comparable to black tea (Hartwig *et.al.*, 2012).

Saponins are highly water-soluble substances that are present in many types of plants. Structurally, saponins two portions, a lipophilic one called sapogenin or aglycone, which may be triterpene or steroidal in nature, and another portion of hydrophilic character made up of sugars.

It has been posed that saponins are one of the factors that contribute to the usual bitter flavour of the infusions prepared with *I. paraguariensis.* Many therapeutic effects have been attributed to this group of compounds apart from their contribution to organoleptic properties. They include anti-inflammatory and hypocholesterolemic properties, antibacterial, antifungal, antiparasitic, and antiviral activity. They are also cytotoxic and antitumor substances (Taketa *et.al*., 2004; Puangraphant and de Mejía, 2009; Sugimoto *et.al.*, 2009; Treter *et.al*., 2010; Puangraphant et.al., 2011a). *Yerba mate* leaves are rich in triterpenic saponins (between 1 to 1.5 % total dry weight). More than twenty saponins were detected in the aerial parts of the yerba

mate plant. Among them, the most common are the 1,2,3,4, and 5 matesaponins and the J1a, J1b, J2a, J2b, J3a y J3b saponins (Gosmann and Schenkel, 1989; Gossman *et.al..*, 1995; Gnoatto *et.al,.*2005; De Souza *et.al*., 2011; Nagamoto *et.al.*, 2022)

Gnaotto et.al., (2005) determined the saponin content of an infusion made by using 15g of *yerba mate* in 100mL of boiling water, allowing the system to infuse for 10 minutes and they obtained a value of 0,35 g/L.

Methylxanthines are a kind of alkaloid derived from the purine that is found in *yerba mate* and other plant-based foods such as tea (*Camellia sinensis*), coffee (*Coffea spp*.), cocoa (*Theobroma cacao*), and *guaraná* (*Paullinia cupana*). Purine alkaloids are secondary metabolites of the higher plants that play a key defensive role against insects and other pathogens. They also have allelopathic effects. Stimulant properties in *yerba mate* are traditionally related to the presence of these substances. The methylxanthines found in *yerba mate* are caffeine (1, 3, 7-trimethyl xanthine), theobromine (3, 7-dimethylxanthine), and theophylline (1, 3-dimethylxanthine). Regarding these three compounds, caffeine is the most abundant (0.80 – 2.90 % in dry matter of *I paraguariensis* leaves), then, theobromine (0,07 - 1,00% in dry matter of *I paraguariensis* leaves), and finally theophylline, although this substance has not been undoubtedly reported in *yerba mate* samples. (Mazzafera, 1994; Athayde *et. al.,* 2007; Brumovsky *et. al.,* 2009)

Caffeine is the most widely consumed stimulant worldwide and the average intake per person is about 200 mg, which causes pharmacologically active blood concentrations. It has been proved that this methylanthine is a non-selective antagonist of adenosine receptors which are in charge of the central nervous system's inhibitory neuromodulatory processes.

Alertness increases, tiredness, and fatigue sensation decrease, a boost in the ability to sustain intellectual effort, and the retaining of the state of wakefulness can be mentioned among the main effects of caffeine. In the same way, caffeine activates brain reward circuits, stimulates breathing, increases blood pressure, heart frequency, and heart muscle contraction force (without risk even at a single 450g dose) generates vasodilatation at the muscle level, stimulates lipolysis in fat tissue and increases gastric secretion. It has not been proven if caffeine has a diuretic effect or not. (Barreda Abascal *et. al*., 2012; Falconi *et. al.,* 2013; de Mejía and Ramírez Mares, 2014; Temple *et. al*., 2017; Verster and Koenig, 2018)According to scientific reports, half a litre of *mate* provides 0,35 to 0,45 g of caffeine, whereas 500 mL of *tereré* provides about 0,2 g. On the other hand, 200 mL of *mate* tea contains 0,02 to 0,04 g of these stimulants (Ramallo *et. al.,* 1998, Maiocchi *et. al*., 2012)

Final Remarks

Yerba mate infusions are low in calories, have low levels of sodium, and do not contain lipids. What is more, 500mL of *mate* provides considerable amounts of thiamine and pyridoxine vitamins.

Yerba mate infusions are rich in bioactive compounds such as polyphenols, methylxanthines, and saponins. All these compounds are responsible for the infusions' functional properties, which are prepared using *yerba mate*. Due to their biological activity, they provide nervous system stimulant effects and cooperate in preventing chronic and degenerative diseases, among other functions.

Infusions prepared with *yerba mate* contribute to daily hydration representing an intelligent form of water intake. As mentioned above, they are low-calorie, low-sodium beverages that also provide considerable amounts of biologically active compounds (polyphenols, methylxanthines, and saponins) and thiamine and pyridoxine vitamins.

Considering the proven anti-nutritional effect of polyphenols as related to mineral micronutrients, a strong recommendation is infusions prepared with yerba mate should be consumed away from main meals.

Drinking *mate, tereré,* or *mate* tea is a healthy habit. Together with a balanced diet, daily fruit and vegetable intake, physical exercise, avoiding smoking, and reducing the intake of salt and alcoholic beverages, contribute to the general well-being and promote the consumers' health.

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