

DETERMINATION OF THE INTAKE TEMPERATURE OF THE BEVERAGE DURING HOT MATÉ CONSUMPTION

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Abstract– The International Agency for Research on Cancer (IARC) has determined that temperatures above 65°C in hot beverages could be potentially carcinogenic. If they are consumed below 65°C are considered as non-carcinogenic to humans. Coffee and tea are consumed in cups and the infusion is put in direct contact with the mouth. In contrast, in hot maté a device similar to a straw is used to sip the infusion. Therefore, the temperature of the infusion when reaching the consumer's mouth is generally lower than the temperature of the water used to prepare the infusion. In this investigation usual conditions of consumption of hot maté by sensorial analysis were determined. Taking these conditions into account, experiments were carried out using temperature sensors to determine the infusion temperature when entering the mouth of the consumer and the variables influence it. Our findings suggest that the infusion temperature at the point of consumption is always below 58°C and is influenced by the water temperature, the amount of yerba maté and the frequency of sipping.

Keywords– Hot maté, temperature, drinks, consumers' preference.

I. INTRODUCTION

Yerba Maté (*Ilex paraguariensis* Saint Hilaire) is a tree that grows in the central region of the MERCOSUR (Argentina, Brazil and Paraguay). A very much consumed beverage (the maté) is prepared from its leaves and branches in this region. In Argentina, Paraguay, Uruguay, and the south of Brazil, the annual consumption is about 6-8 kg per capita.

The yerba maté elaboration process is very particular. Leaves and branches are thermally treated at high temperatures in order to inactivate enzymes to avoid the browning of the leaves. Then they are dried in cross flow driers with gases at 80°C to 120 °C. After drying to a moisture content between 3 % and 5 %, leaves and branches are ground in order to reduce their volume. In Brazil, the product is consumed immediately after grinding, but in Argentina Paraguay and Uruguay, the material is aged in order to change its flavor (Holowaty *et al.*, 2014; Zaions *et al.*, 2014).

Besides nutritional compounds, other compounds with biological activity are found in yerba maté, such as polyphenols (8-10 %), caffeine and other xantines (0.8 – 1.2 %), and saponins (0.3-0.5%) (Zaions *et al.*, 2014; Molin *et al.*, 2014; Hartwig *et al.*, 2013; Cansian *et al.*, 2008; Bastos *et al.*, 2006).

Yerba maté, like tea and coffee, is generally consumed as a hot infusion. Consumption of hot food and

beverages, was questioned in 1991 by the International Agency for Research on Cancer (IARC), because they are classified as “possibly carcinogenic to humans”, associated with cancer of upper gastrointestinal tract (Group 2A).

In 2016, a new revision of consumption of hot maté and coffee was carried out (IARC Monograph 116). After reviewing the papers, the conclusion that was reached was that they could be potentially carcinogenic if they are consumed at temperatures above 65 °C (Group 2A), while warm maté (below 65 °C) was classified as “no carcinogenic to humans” (Group 3).

Coffee, tea and other infusions are generally consumed in cups, but yerba maté is consumed in a very different way. A portion of 20 g to 100 g of yerba maté is put in a 100-ml to 300-ml container. About 30 ml of hot water at 65 °C to 95 °C (Pagliosa *et al.*, 2009; Santa Cruz *et al.*, 2002) is poured on the yerba maté and then sipped with a “bombilla,” which is device similar to a straw with a filter in the lower end that is in contact with the solid (Fig. 1). This procedure is repeated until finishing 1 l of water approximately (Schmalko *et al.*, 2012; Heck and De Mejía, 2007).

Temperature of the sipped liquid is expected to be lower than temperature of the poured liquid. This fact is due to the heat losses through the container and the “bombilla” walls during the consumption process.

Hot maté is consumed in very different forms. Containers of different materials (wood, calabash, ceramics, glass and metals), different quantities of yerba mate (from 20 g to 100 g), different forms of “bombilla” (generally metallic) and different water temperatures (from 65°C to 95 °C) are used. There are no previous studies about preference of consumers, so previous sensorial analyses are needed in order to determine the preferences of container material, solid quantity, “bombilla” material and their relationship with water temperature.

All these variables and the sipping frequency are expected to influence the intake temperature of the infusion (temperature of the infusion when entering the mouth of the consumer). No previous papers measuring the intake temperature during hot maté consumption were found.

The aim of this research was to measure the intake temperature of the infusion during hot maté consumption, considering different water temperatures, container material, yerba maté quantity and sipping frequency.

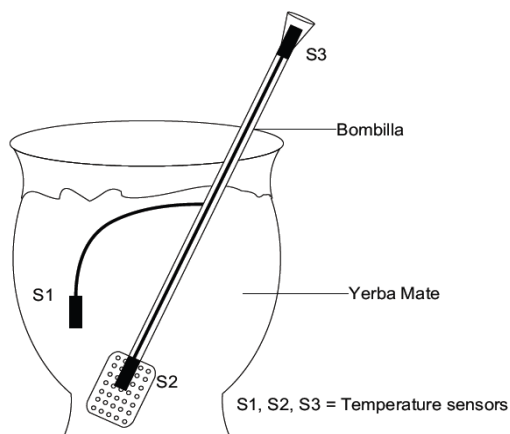


Figure 1. Measurement equipment

II. METHODS

A. Sensory Evaluation

Influence of the solid quantity and water temperature

In order to evaluate the influence of solid quantity and water temperature on consumer preferences, four sensorial assays were performed with 38 usual consumers of hot maté, using individual cubicles at room temperature ($27^{\circ}\text{C} \pm 1^{\circ}\text{C}$).

Assays were carried out with 30 g, 40 g, and 50 g of yerba maté; water temperatures of 70°C , 80°C , and 90°C ; and a sipping frequency of 60 s.

Each panelist was provided with 3 ceramic containers with yerba maté, a stainless steel “bombilla” located inside the yerba maté, and hot water in an insulated container. The ceramic containers were covered with a white paper in order to avoid visual preferences. They received the following instructions:

- start with the left container
- soak the yerba maté with the hot water
- let it rest for a minute
- sip the infusion
- repeat the operation 3 times
- repeat this procedure with the others containers.

The panelists were asked to grade the infusion temperature using a 5-point hedonic scale as 1) Cold, 2) Warm, 3) Adequate, 4) Hot, and 5) Very hot.

Influence of container material

In order to evaluate the influence of the container material on the infusion temperature independent assay were carried, 20 panelists working in individual cabinets were asked to choose the material of their preference using 40 g of yerba maté and hot water at 80°C . They were asked to repeat the instructions given in the last item and use the 5-point scale considering infusion intake temperature. The following container materials were used: wood, calabash, ceramics, glass, and metal.

Influence of sipping frequency

The procedure given in the last item was repeated, with 20 panelists using three sipping frequency: 30 s, 60 s, and 120 s.

B. Measurements with the temperature sensors

Data acquisition

To measure the temperature of the infusion during hot maté consumption, temperature sensors connected to a data acquisition system were installed at three points in the container and “bombilla.” S1, in the solid; S2 on the “bombilla” filter, and S3 on the “bombilla” near the mouth (Fig. 1). The precision of the temperature sensors was $\pm 0.5^{\circ}\text{C}$ and the operation range was of -55°C to 125°C . Software, in Java language, was developed in order to record temperature data each 2 s. The panelists could select their preference on a digital display.

Procedure

In each experiment, 9 trained panelists followed the subsequent procedure:

- add 100 ml of hot water
- sip the infusion
- let it rest for 1 min
- repeat the operation three times
- repeat the procedure for each sample
- qualify your preference of infusion temperature for each sample using scale on display.

Influence of yerba maté quantity and water temperature

In order to study the influence of the yerba maté quantity and water temperature, three ceramic containers with different quantities of yerba maté (30 g, 40 g, and 50 g) and hot water was used. The procedure was repeated with three water temperatures: 70°C , 80°C and 90°C . Temperature on the three sensors was recorded.

Influence of container material

For this experiment five different container materials (wood, calabash, ceramics, glass, and metal), 40 g of yerba maté, and hot water at 80°C were used. Temperature on the three sensors was recorded.

Influence of sipping frequency

Experiments were carried out using three frequencies (30 s, 60 s and 120 s), 40 g of yerba maté, and hot water at 80°C . Temperature on the three sensors was recorded.

Statistical analysis

To compare values resulted of sensory analysis and maximum and mean temperature values registered by the sensors, an ANOVA test with a confidence limit of 95 % was used. The StatGraphics statistical package (Statgraphics, 2009) was used to process the data.

III. RESULTS AND DISCUSSION

A. Sensory Evaluation

The sensorial evaluations were carried out with 38 consumers in order to determine the best mark in the hedonic scale for water temperature and yerba maté quantity. Consumers' age ranged from 22 to 45 years old and 55% of them were female. Both variables, influenced the sensorial mark, as can be observed at the Mean Graphics of the ANOVA in Fig. 2. The range of the mark values was near the value of 3 (Adequate). Considering the interaction plot (Fig. 3), three pair of values can be selected according to the best qualification ($=3$), 70°C - 30 g, 70°C

- 40 g, and 80 °C - 40 g. Both mean values (of water temperature (80 °C) and yerba maté quantity (40 g)), were selected in order to be used in the sensor temperature determination.

No significant differences were found between the container material and sipping frequency.

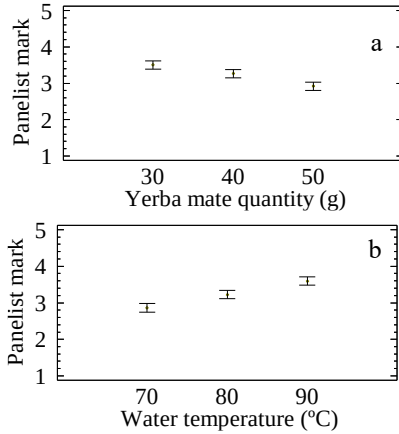


Figure 2. Panelist mark obtained in the sensorial analysis 1) Cold, 2) Warm, 3) Adequate, 4) Hot, and 5) Very hot) considering (a) Yerba maté quantity and (b) Water temperature.

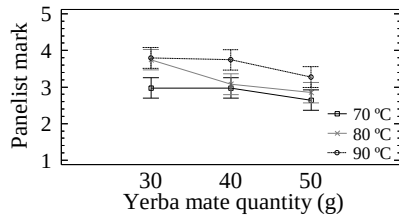


Figure 3. Interaction Plot of the panelist mark obtained in the sensorial analysis 1) Cold, 2) Warm, 3) Adequate, 4) Hot, and 5) Very hot).

B. Measurements with the sensor temperature

Data of temperature sensors were recorded during hot maté consumption. In each assay, the panelist, poured hot water three times, at different frequencies. Some typical profiles are shown in Figure 4. The higher temperature profile (S1) corresponds to the sensor located in the solid, where the hot water is poured. A similar profile is observed in the sensor located at the filter (S2). Temperature at both sensors (S1 and S2) is below the poured water temperature, reaching quickly a constant temperature.

The sensor located at the end of the “bombilla” (S3) has a very different profile and the higher temperatures coincide with the start of the sipping. The profile of S3 is characterized by a sharp increase and a slow decrease. The low decrease is due to the heat losses through the “bombilla. This behavior is repeated in each sipping. The temperature of S3 is always below of the others sensors at least by 15 °C.

In order to analyze the data, maximum and mean temperatures at the end of the “bombilla” were determined.

Influence of water temperature and solid quantity

The panelists evaluated simultaneously the influences of water temperature (70 °C, 80 °C, and 90 °C) and yerba maté quantity (30 g, 40 g, and 50 g) on the infusion temperature at the end of the “bombilla”.

Maximum and mean temperatures were influenced by water temperature with $P < 0.05$. As it can be expected, the increase on water temperature produced and increase in the maximum and mean temperatures at the end of the “bombilla” (Fig. 5). But very low variation of temperature (maximum and mean) was found between the panel-

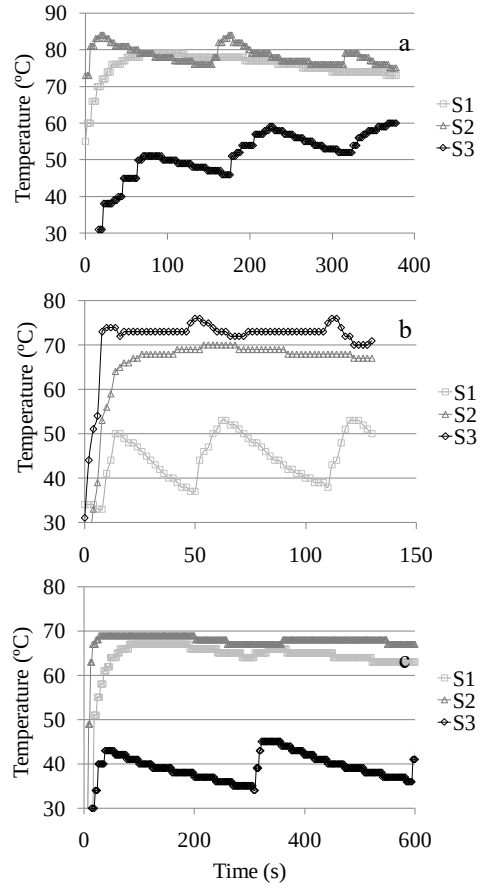


Figure 4. Thermal profile of the three sensors: S1 located in the yerba maté, S2 located in the filter, and S3 located at the end of the “bombilla,” near the mouth. Experiment “a” corresponds to a sipping frequency of 30 s, “b” to 60 s and “c” to 120 s, using 40 g of yerba maté and hot water at 80 °C.

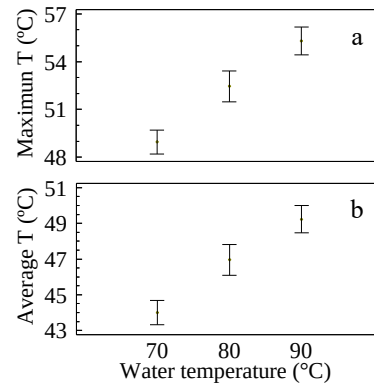


Figure 5. Mean values and confidence limits (95%) of the Maximum temperature (a) and Mean temperature (b) at the end of the “bombilla,” using water at different temperatures (Experimental conditions: ceramic container, 30 g, 40 g and 50 g of yerba maté and a sipping frequency of 60 s).

ists (minor than ± 1 °C).

No significant differences ($P>0.05$) were found between the three yerba mate quantities and the maximum temperature of the infusion at the end of the “bombilla,” which (Fig. 6a). However, an increase in yerba mate quantity produced a slow decrease of the maximum temperature. A similar result was found when the mean temperature at the end of the “bombilla” was analyzed (Fig. 6b).

Considering both factors, a variation from 48 °C to 57 °C of the maximum temperature and from 43 °C to 50 °C of mean temperature was found.

When both factors were simultaneously analyzed, the interaction resulted non significant, producing parallel lines in the interaction plot (Fig. 7).

Influence of the container material

The panelists evaluated the influence of 5 container materials (wood, calabash, ceramics, glass and metal) on infusion temperature at the end of the “bombilla.” No significant differences ($P>0.05$) between the materials and the maximum temperature were found. Maximum temperature varied between 49 °C to 56 °C. A similar result was found when the mean temperatures were analyzed. Mean temperature varied between 45 °C to 50 °C.

Influence of the sipping frequency

The panelists evaluated the influence of three sipping frequency (30 s, 60 s and 120 s) on water temperature at the end of the “bombilla”. Sipping frequency influenced statistically in both variables (maximum and mean temperature) (Fig.8). Maximum temperatures sharply decrease with an increase of the time (54 °C to 58 °C for 30 s; 52 °C to 56 °C for 60 s; and 47 °C to 51 °C for 120 s). Mean temperature for 30 s and 60 s resulted similar (from 46.5 °C to 48.5 °C) and different from 120 s (from 44 °C to 46 °C).

Considering all the experiments, maximum temperature at the end of the “bombilla” varied between 38 °C and 58 °C. In no case temperature of 58 °C was exceeded. Mean temperature, during hot maté consumption varied between 37 °C to 55 °C.

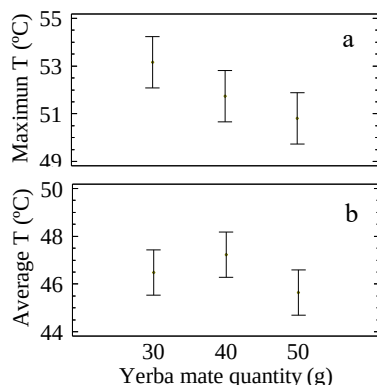


Figure 6. Mean values and confidence limits (95%) of the Maximum temperature (a) and Mean temperature (b) at the end of the “bombilla,” using different yerba maté quantities (Experimental conditions: ceramic container, 70 °C, 80 °C and 90 °C of water temperature and a sipping frequency of 60 s).

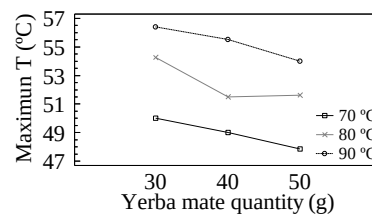


Figure 7. Interaction Plot of Maximum temperature in S3, considering Yerba maté quantity and Water temperature.

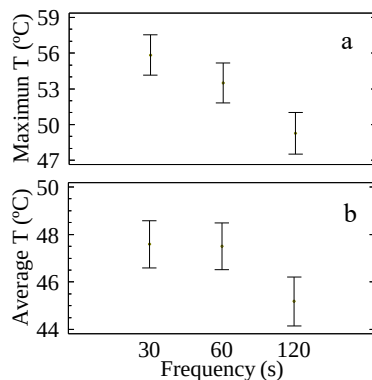


Figure 8. Mean values and confidence limits (95%) of the Maximum temperature (a) and Mean temperature (b) at the end of the “bombilla,” using different sipping frequency (Experimental conditions: ceramic container, water temperature: 80 °C and 40 g of yerba maté)

Research has been done on the consumption temperature of others infusions, mainly, coffee and tea. Brown and Diller (2008) and Borchgrevink *et al.* (1999) studied coffee consumption temperature and preference of them. They found that consumers preferred relatively hot temperatures (62.8 °C to 68.3 °C). In tea, Wu *et al.* (2009) and Islami *et al.* (2009, 2008) found that consumers preferred relative high infusion temperatures (higher than 65 °C). They classified infusion temperature consumption in three groups: warm (< 65 °C), hot (65-69 °C) and very hot (≥ 70 °C). In both cases (coffee and tea) the infusion was served in cups and temperature was measured in the cups.

Consequently, consumption liquid temperature of yerba maté can be considered lower than consumption temperature of coffee and tea.

IV. CONCLUSIONS

When studying the temperature of consumption of hot mate prepared under various conditions (different water temperatures, yerba mate quantities, pouring frequencies and container materials), it was observed that when the infusion reaches the consumer’s mouth, it never exceeded 58 °C. It is important to mention that this value is well below the temperature considered as potentially carcinogenic (65 °C) by the IARC (International Agency for Research on Cancer).

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