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Storage of yerba maté in controlled atmosphere

Armazenamento de erva-mate em atmosfera controlada

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ABSTRACT

The aim of this study was to evaluate the effect of controlled atmosphere in the change of color, chlorophyll degradation and phenolic compounds concentration in yerba maté thickly ground ("cancheada"*) and thinly milled (*"socada"*). Yerba maté samples from the towns of Arvorezinha (RS - Brazil) and São Mateus do Sul (PR - Brazil) were stored in four levels of oxygen (1, 3, 6 and 20.9kPa of O_2) and four levels of carbon dioxide (0, 3, 6 and 18kPa of CO_2) and then were analyzed, after nine months of storage. According to the results, the O_2 partial pressure reduction decreased the loss of green coloration, kept a higher content of chlorophylls and of total phenolic compounds. In relation to the different levels of CO_2, a response as remarkable as O_2 was not observed. The yerba maté that was thickly ground (*"cancheada"*) presented a better storage potential than the one thinly milled (*"socada"*) in the storage with O_2 and with CO_2. The 1kPa of O_2 condition kept the yerba maté greener and with a higher content of chlorophylls and of total phenolic compounds after nine months of storage. The CO_2 partial pressure kept the yerba maté coloration greener and with a higher content of chlorophylls and of total phenolic compounds, regardless of the level used, in the maté from both cultivation areas.*

Key words: ***Ilex paraguariensis****, storage, coloration and phenolic compounds.*

RESUMO

O objetivo deste estudo foi avaliar o efeito da atmosfera controlada na alteração da cor, degradação da clorofila e concentração de compostos fenólicos em erva-mate cancheada e socada. Amostras de erva-mate provenientes de Arvorezinha (RS) e São Mateus do Sul (PR) foram armazenadas em quatro níveis de oxigênio (1, 3, 6 e 20,9kPa de O_2) e quatro níveis de gás carbônico (0,3, 6 e 18kPa de CO_2), as quais foram analisadas ao final de nove meses de armazenamento. Segundo os resultados, a redução das pressões parciais de O_2 reduziu a perda da coloração verde, manteve maior teor de clorofilas e de compostos fenólicos totais. Em relação aos diferentes níveis de CO_2, não se constatou uma resposta tão marcante como na de O_2. Tanto no armazenamento com O_2 como com CO_2, a erva-mate cancheada apresentou melhor potencial de armazenamento do que a erva-mate socada. A condição com 1kPa de O_2 manteve a erva-mate mais verde, maior teor de clorofilas e compostos fenólicos totais após 9 meses de armazenamento. A pressão parcial de CO_2, independente do nível utilizado, mantém a coloração da erva-mate mais verde, maior teor de clorofilas e compostos fenólicos totais nas ervas provenientes dos dois locais de cultivo.

Palavras-chave: ***Ilex paraguariensis,*** *armazenamento, coloração e compostos fenólicos.*

INTRODUCTION

The yerba maté (***Ilex paraguariensis***) is a native species that stands out as an economical, social and ecological source for the southern region of Brazil, northern and eastern region of Argentina and Paraguay. Brazil is one of the world's greatest producer of yerba maté and the state of Paraná is responsible for a great part of the national production (SIDRA, 2012), serving the maté companies for domestic consumption, besides providing raw material to the exporter industrial segment.

A great part of the Brazilian yerba maté production is addressed to the consumption in forms

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of beverages such like "*chimarrão*", compound for "*chimarrão*", tea and "*tererê*". Considering its complex chemical composition, due to the presence of bioactive organic compounds (caffeine, phenolic acids and saponins) and other plant extracts, the prospects for its use in new areas, such as the elaboration of extracts and compounds or as source of pharmaceutical products for phytotherapy, are promising (VIEIRA et al., 2009).

The product of yerba maté is obtained from the ***Ilex paraguariensis*** branches and has as main quality index for the Brazilian consumers the green color (VALDUGA et al., 2005). The yerba maté color is owed to the presence of chlorophyll and the intensity of the green has a direct relation to the concentration of this pigment (MORAWICKI et al., 1999).

One of the greatest challenges of the maté industry is the instability of the bright green color during its storage. For this reason the yerba maté is harvested throughout the year in order to obtain a green product without any odd flavor, result of fast aging process and presence of fungi (ROBERTSON, 1993). However, the best quality product is obtained from May to August, when the plants sprout and these new buds are singed, a step of the raw material processing *("sapeco" – heat treatment)*, giving the yerba maté a burnt taste. Later in the annual cycle, the plant bears fruits which give the maté a bitter taste that is not desired by the Brazilian consumer.

Therefore, the ideal for the maté industry would be to harvest and process the raw material during the appropriate period (May to August) and to store it either thickly ground or ready for consumption as thinly milled. Nevertheless, the yerba maté cannot be stored under ambient conditions for a long period of time without great quality losses, that occur due to humidity and presence of oxygen, which causes a faster oxidation of chlorophylls, causing a yellow or dark brown coloration that changes the taste of the "*chimarrão*" (TEXEIRA NETO, 1999).

When the branches are harvested at the proper time and the processed product is marketed during the offseason, the storage in controlled atmosphere can be an alternative to maintain the quality and increase the maté preservation period. However, there is no information in the literature regarding this storage and its impact in the quality of the yerba maté product.

Thereby, the objective of this research was to evaluate the effect of the controlled atmosphere storage in the change of color, chlorophyll degradation and phenolic compounds concentration in the thick ground form ("*cancheada*") of yerba maté and in the one ready for consumption ("*socada*"), from the towns of Arvorezinha (RS - Brazil) and São Mateus do Sul (PR - Brazil).

MATERIAL AND METHODS

The raw material used was the thickly ground yerba maté ("*cancheada*") and the processed form for "*chimarrão*" ("*socada*"), from Arvorezinha (RS - Brazil) and São Mateus do Sul (PR - Brazil) cities. Between the harvest of the raw material and the preparation of the yerba maté 15 days elapsed, in order to ensure a high quality product. The yerba maté leaves were submitted to the standard industrial processing of drying and milling to get the powder yerba maté, "chimarrão" type at the Vier company in the town of Santa Rosa (RS – Brazil). For each treatment, four repetitions of the 1kg experimental unity of maté were used. The samples were stored during nine months, in hermetically sealed experimental mini chambers, with a 0.232m^3 volume, which were connected by plastic pipes to a control desk with gas analyzers. The mini chambers were placed inside the refrigeration room at a temperature of 20±0.2ºC.

The yerba mate was stored in four levels of oxygen (1, 3, 6 and 20.9kPa of O_2) and four levels of carbon dioxide (0, 3, 6 and 18kPa of CO_2). The controlled atmosphere (CA) conditions were installed by the injection of nitrogen (N_2), from a N_2 generator that works by the "Pressure Swing Adsorption" (PSA) principle. Through the dilution with N_2, the O_2 partial pressure was reduced until the pre established level for each treatment. The CO_2 partial pressures were obtained through the injection of this gas, from high pressure cylinders, inside the mini chambers. During the storage period, the gases partial pressures (O_2 and CO_2) were monitored and corrected once a week, using Schele analyzers.

In order to determine the yerba maté color a Minolta CR 310 colorimeter was used, operating in the CIELAB system. Previously to the color determination, the yerba maté samples were manually sieved, with the use of test strainer with an 800µm mesh aperture, to eliminate white sticks left from the branches milling. Then the samples were stowed and compacted in Petri dishes. The color determinations were performed in triplicates.

The total chlorophylls were evaluated according to the method described by LICHTENTHALER (1987) and the total phenolic compounds were determined by the Folin – Ciocalteu colorimetric method, described by SINGLETON et al. (1999), using Gallic acid as standard.

An analysis of variance (ANOVA) was carried out for all the parameters evaluated. When the ANOVA was significant, the parameters were compared by Tukey's test, at 5% of probability of error. A *Pearson* correlation analysis was also carried out.

RESULTS AND DISCUSSION

The storage condition factor (O_2), the yerba maté types and its interaction presented a significant influence ($P<0.05$) in the color instrumentally determined in the samples from Arvorezinha and São Mateus do Sul. The increase of the Hue angle is related to an enhancement green color and consequently, a reduction of the yellow. By this reasoning, it is observed that the yerba maté thickly ground ("*cancheada*") from both towns kept greener and less yellow during the storage at 1kPa of O_2 (Table 1). In the same table it can be seen that as the O_2 concentration increases, a significant decrease in the green coloration of the yerba maté occurs and the same response was found in both sites evaluated in the present study. This fact is related to the oxidation of chlorophylls when the O_2 partial pressures increases (Table 1), once studies have shown that the yerba maté green coloration has a strict relation to the chlorophylls concentration (MORAWICKI et al., 1999; BOBBIO & BOBBIO, 1995). Considering the two types or yerba maté ("*socada*" and "*cancheada*") and the two sites (Arvorezinha e São Mateus do Sul), a better maintenance of the green color in the yerba maté is observed in all the O_2 partial pressures.

In the yerba maté storage with CO_2, no significant differences between 3, 6 and 18kPa CO_2 partial pressures were found (Table 2). However, these three CO_2 levels differed from 0kPa CO_2, which showed lower green coloration in the two types of yerba maté and sites. When comparing the two types of maté in both sites, the thickly ground ("*cancheada*") coloration was greener and less yellow; regardless the storage conditions (Table 2).

The total concentration of chlorophylls in both types of yerba maté and sites analyzed was reduced after nine months of storage in controlled atmosphere with low oxygen levels (Table 1) and with high carbon dioxide levels (Table 2). According to the literature, an exponential reduction of the chlorophylls occurs during the storage of yerba maté (CABRAL-MALHEIROS, 2010).

Table 1 - Hue angle, total chlorophylls concentration and total phenolic compounds in from yerba maté ("*cancheada*") and ("*socada*") from Arvorezinha (RS) and São Mateus do Sul (PR) stored at 20°C in 0, 1, 3, 6 and 20.9kPa of O_2, during nine months.

	Oxygen (kPa)				
	Arvorezinha (RS)				
Yerba maté	Initial	20.9	1.0	3.0	6.0
	Hue angle (h^0)				
Cancheada	112.5	103,7Da*	109.6Aa	108.4Ba	107.2Ca
Socada	110.4	101,3Db	107.9Ab	106.1Bb	104.9Cb
	Total chlorophylls (µg g^{-1})				
Cancheada	2814.6	687.0Da	1010.8Aa	924.2Ba	830.5Ca
Socada	2789.5	560.4Bb	617.1Ab	574.2Bb	558.5Bb
	Total phenolic compounds (mg g^{-1})				
Cancheada	223.4	127.1Ca	177.9Aa	163.3Aa	137.2Ba
Socada	191.2	79.3Cb	99.1Ab	64.1Bb	57.8Bb
	São Mateus do Sul (PR)				
	Hue angle (h^0)				
Cancheada	114.4	104.1Da	111.3Aa	110.2Ba	108.4Ca
Socada	110.1	101.9Db	109.9Ab	107.5Bb	106.1Cb
	Total chlorophylls (µg g^{-1})				
Cancheada	2006.7	684.0Da	1105.7Aa	1005.1Ba	838.7Ca
Socada	2003.5	570.3Bb	865.1Ab	596.1Bb	564.9Bb
	Total phenolic compounds (mg g^{-1})				
Cancheada	222.5	96.2Ca	143.5Aa	139.2Aa	128.8Ba
Socada	165.3	57.7Cb	64.9Ab	63.4Ab	60.9Bb

*Averages followed by the same letters, capital letters in the lines and lower case letters in the columns, do not differ between each other, according to Tukey test, 5% of probability of error.

Table 2 – Hue angle, total chlorophylls concentration and total phenolic compounds in from to yerba maté ("*cancheada*") and ("*socada*") from Arvorezinha (RS) and São Mateus do Sul (PR) stored at 20°C in 0, 3, 6 and 18 kPa of CO_2, during nine months.

Yerba maté	Carbon dioxide (kPa)				
	Arvorezinha (RS)				
	Initial	0	3	6	18
	Hue angle (h^0)				
Cancheada	112.5	103.7Ba*	104.8Aa	104.8Aa	104.6Aa
Socada	110.4	101.3Bb	102.2Ab	102.9Ab	102.1Ab
	Total chlorophylls (µg g^{-1})				
Cancheada	2814.6	687.0Ca	847.1Aa	867.0Aa	736.4Ba
Socada	2789.5	677.4Ca	704.2Bb	814.0Aa	714.0Ba
	Total phenolic compounds (mg g^{-1})				
Cancheada	223.4	127.1Ba	167.2Aa	162.1Aa	164.3Aa
Socada	191.2	79.3Bb	107.8Ab	105.5Ab	102.9Ab
	São Mateus do Sul (PR)				
	Hue angle (h^0)				
Cancheada	114.4	104.1Ba	105.7Aa	105.9Aa	105.5Aa
Socada	110.1	101.9Bb	102.9Ab	102.8Ab	102.9Ab
	Total chlorophylls (µg g^{-1})				
Cancheada	2006.7	684.0Ca	765.3Ba	824.6Aa	723.3Ba
Socada	2003.5	570.3Cb	700.5Ab	751.6Ab	649.4Bb
	Total phenolic compounds (mg g^{-1})				
Cancheada	222.5	96.2Ca	146.5Aa	137.2Aa	143.8Aa
Socada	165.3	57.7Cb	109.2Ab	108.1Ab	106.8Ab

*Averages followed by the same letters, capital letters in the lines and lower case letters in the columns , do not differ between each other, according to Tukey test, 5% of probability of error.

Chlorophylls degradation in the maté stored under low O_2 and also under high CO_2 was greater in the thinly milled form of yerba maté ("*socada*") in both sites. These processes may be linked to the loss of color during the storage of yerba maté, as it has been suggested for other vegetables (KING et al., 2001). Regarding the storage conditions, the O_2 partial pressure of 1kPa, both in the yerba maté thickly ground ("*cancheada*") as in the thinly milled ("*socada*"), resulted in a higher maintenance of the chlorophylls content after storage, regardless its place of origin (Arvorezinha or São Mateus do Sul).

The greener coloration of thickly ground ("*cancheada*") yerba mate indicates less chlorophylls degradation, once the chlorophylls content has a high correlation to the coloration instrumentally measured (Table 3). However, the chlorophylls concentration and the green coloration responses, on yerba mate stored under CO_2 levels, did not follow a pattern as perfect as in the storage with O_2, nonetheless one still can infer that the green color modification occurs due to changes in the chlorophylls content (BOBBIO & BOBBIO, 1995). The lower chlorophylls degradation possibly has a relation to the smaller O_2 contact surface, considering that the yerba maté "*cancheada*" is thickly ground reducing the O_2 contact surface in relation to the yerba maté "*socada*" which is thinly milled, since a bigger surface of material propitiates stability problems due to the humidity absorption and to the fostering of oxidative reactions. Other studies have also pointed that the granulometry of the maté is related to the chlorophylls degradation (KING et al., 2001; SANTOS, 2004).

A correlation analysis was conducted with the data obtained from both sites and types of maté, in the storage with O_2 (1, 3, 6 and 20.9kPa) and with CO_2 (0, 3, 6, and 18kPa), crossing the color parameter (h°) with the total chlorophylls. There was a significant correlation ($P<0.05$) between the parameters (Table 3). Similar situation occurred in CABRAL-MALHEIROS (2007) research. This result shows that the chlorophylls content variation influences significantly the yerba maté coloration, in other words, when the chlorophylls content decreases the hue angle values decline and vice versa. One can also infer that the correlation coefficients are mostly high, which shows high influence of variable on the other.

Concerning the phenolic compounds, it is possible to infer that the yerba maté stored in the thick ground form ("*cancheada*") presents a

Table 3 - Pearson correlation coefficient (P < 0.05) between the hue angle (h°) and total chlorophylls, to yerba maté ("*cancheada*") and ("*socada*") from Arvorezinha (RS) and São Mateus do Sul (PR) stored during nine months.

---------- Oxygen (kPa) ----------				
---------- Arvorezinha (RS) ----------				
Yerba maté	1	3	6	20.9
Cancheada	0.97	0.88	0.77	0.98
Socada	0.98	0.90	0.96	0.81
---------- São Mateus do Sul (PR) ----------				
Cancheada	0.94	0.60	0.92	0.88
Socada	0.92	0.55	0.99	0.93
---------- Carbon dioxide (kPa) ----------				
---------- Arvorezinha (RS) ----------				
	0	3	6	18
Cancheada	0.89	0.86	0.84	0.99
Socada	0.91	0.78	0.78	0.85
---------- São Mateus do Sul (PR) ----------				
Cancheada	0.88	0.97	0.99	0.88
Socada	0.92	0.75	0.93	0.98

higher concentration of those than the one stored in the thin milled ("*socada*"), nevertheless losses occurred during the storage with low levels of oxygen and high levels of carbon dioxide (Table 1 and 2). BURGARDT (2000) and VALDUGA et al. (2003) reported in their studies that the phenolic compounds variation is associated to factors such as the division degree of the yerba maté (granulometry). The oxygen levels reduction and the carbon dioxide increase presented a positive effect in the phenolic compound concentration, although is possible to verify losses throughout the storage. Specifically in relation to the O_2 partial pressures, a decrease in the phenolic compounds content was found until 3kPa of O_2 and this did not differ significantly from the lower condition of O_2 (1,0kPa). Whereas in the different levels of CO_2, the same response to the storage in O_2 were not observed, significant difference occurred only between the storage without CO_2 and with CO_2, regardless of the partial pressure used. As to the form of yerba maté, thickly ground ("*cancheada*") and thinly milled ("*socada*"), phenolic compound contents were significantly greater in the thick maté, in both origin sites (Table 2).

CONCLUSION

The findings indicate that the controlled storage condition with 1kPa of O_2 keeps the yerba maté greener, with a higher content of chlorophylls and total phenolic compounds after nine months of storage. The CO_2 partial pressure kept the maté greener, with a higher content of chlorophylls and total phenolic, regardless of the level, in both cultivation areas.

The yerba maté that was thickly ground ("*cancheada*") presents greater storage potential than the one thinly milled ("*socada*").

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