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ORIGINAL RESEARCH PAPER

EXPLORING THE PHYSICO-CHEMICAL, PHYTOCHEMICAL AND SENSORIAL CHARACTERISTICS OF SOME ROMANIAN RED FRUITS TEA INFUSIONS

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Abstract: Red fruits represent an important source of natural antioxidants possessing health-promoting properties. Infusions of red fruit teas are gaining interest and popularity among consumers. The physico-chemical characteristics and phytochemical screening of some red fruits tea infusions were analyzed in the present study using fast and accessible electrochemical and UV-Vis spectroscopic methods. As well, sensorial analysis was carried out through the 7-points hedonic scale method. Our research revealed that the quality of the infusions and the overall acceptance, respectively, are influenced by the brewing time and the proportion of red fruit tea and water used in their preparation. Following the results for the overall degree of satisfaction, the most preferred infusions by consumers were those obtained from Forest fruit tea and Carpathian tea using two bags, and 10 minutes of brewing time. The color intensity, the proportion of red, as well, the content of vitamin C and phytochemical profile of analyzed infusions are correlated with the degree of global satisfaction. The results obtained in the present work delivered valuable information about red fruits tea infusions based on their physico-chemical, phytochemical and sensorial characteristics.

Keywords: *anthocyanins, brewing time, infusion, physico-chemical analysis, phytochemical screening, red fruits tea, sensorial analysis*

INTRODUCTION

Due to their attractive taste and health-promoting properties, being naturally caffeine free, fruit and herbal infusions, also known as tisanes, are widely consumed around the world.

Infusions of red fruit teas, known also as berries herbal tea or red berries infusion, represent an important source of natural antioxidants [1 – 3] and their popularity among the Romanian consumers has increased, especially during the cold season. Several scientific research reported the antioxidants properties, anti-inflammatory and anti-aging actions of dried red fruits infusion [4 – 7]. A recent study proved that enriching black tea infusion with red fruits (e.g., strawberries) can increase the total amount of phenolic compounds, which implicitly leads to the highest antioxidant and antiradical activities among the samples studied [8].

Red fruit teas represent a mixture of dried fruits, flowers, or leaves such as chokeberries (*Aronia melanocarpa* Medik.), strawberries (*Fragaria x ananassa* Duchesne), raspberries (*Rubus idaeus* L.), rosehips (*Rosa canina* fruits), cherries (P*runus avium*), wild strawberries (*Fragaria vesca* L.), cranberries (*Vaccinium vitis-idaea*), blackberries (*Rubus fruticosus* L.), blueberries (*Vaccinium myrtillus* L.), black currants (*Ribes nigrum* L.) and red currants (*Ribes rubrum* L.) berries, etc., as well as apples (*Malus domestica* Borkh.), hibiscus calyces (*Hibiscus sabdariffa*) or coriander leaves (*Coriandrum sativum* L.). It is well-known that red fruits possess radical scavenging capacity due to their high content in polyphenolic compounds (anthocyanins, flavonoids, phenolic acids, etc.) [9 – 11]. Fruit teas may also contain citric acid as acidity regulator, for improving their taste and aroma [4].

The infusions made from red dried fruits have a red-purple color, as well as a fruity sour taste. However, individual choices are also influenced by sensorial properties, beyond interest in health benefits. The sensorial characteristics such as color, aroma and taste contribute to make an appropriate selection from a wide variety of products on the market.

At the same time, it has been demonstrated that some parameters, such as brewing time, temperature and water, are important in the extraction process of phenolic compounds and implicitly on antioxidant activity and the quality of the obtained tea infusions [4 – 7].

Due to consumers' interest in drinking red fruit teas, knowledge about their physico-chemical characteristics, phytochemical and sensorial profile related to the brewing time or other parameters is important. To date, only a few studies have been described by the Romanian researchers about the commercial red fruit teas, generally regarding the content of total phenolics and antioxidant activity [1, 7] or their authentication [12].

Therefore, the aim of the present study was to explore some commercial Romanian red fruits tea infusions in terms of its physico-chemical properties and phytochemical screening using fast and accessible techniques such as electrochemical methods and UV-Vis spectroscopy. As well, the research focused on the sensorial characteristics of red fruits tea infusions in order to find out the consumer preferences and to provide valuable information based on the correlations between the physico-chemical and the phytochemical characteristics.

MATERIALS AND METHODS

Preparation of red fruit tea infusions

Five commercial red fruit teas were purchased from a local market (Table 1). This set of teas was selected from a Romanian manufacturer due to its good popularity [13].

Table 1. *Presentation and composition of red fruit teas used in the present study as declared by the manufacturer*

Tea	Composition*	Code
 **Strawberries and wild strawberries**	aronia, hibiscus flowers, **strawberries 10 %**, **wild strawberries 10 %**, flavors, rose hips, acidity regulator: naturally obtained citric acid, **raspberries**, apples. Contains no synthetic dyes.	**I01**
 **Cranberries and wild raspberries**	aronia, hibiscus flowers, **raspberries 11 %**, flavors, apples, rose hips, **coriander**, acidity corrector: naturally obtained citric acid, **cranberries 2 %.** Contains no synthetic dyes.	**I02**
 **Cranberries and blueberries**	aronia, hibiscus flowers, apples, **strawberries**, **coriander**, flavors, rose hips, **raspberries**, **blueberries 3 %**, acidity corrector: naturally obtained citric acid, **cranberries 2 %**. Contains no synthetic dyes.	**I03**
 **Forest fruits**	aronia, hibiscus flowers, mixture of forest fruits in variable proportions min. 23 % (**raspberries**, **currants**, **gooseberries**, rose hips, **blueberries**, **blackberries**), flavors, acidity regulator: naturally obtained citric acid, apples. Contains no synthetic dyes.	**I04**
 **Carpathian fruits**	aronia, hibiscus flowers, mixture of dried fruits in variable proportions min. 23 % (**strawberries**, **currants**, apples, rose hips, **raspberries**, **cherries**, **blackberries**, **blueberries**), flavors, acidity corrector: naturally obtained citric acid. Contains no synthetic dyes.	**I05**

*According to the product label / Ingredients found in all products: aronia, hibiscus flowers, apples, rose hips, flavors, acidity corrector (citric acid) / Ingredients specific to each product are indicated in bold

According to the producer's declaration [14], the teas were manufactured in compliance with the requirements of the ISO 22000:2018 standard for food safety management system [15] and ISO 9001:2015 for quality management system [16], certificated by TÜV Rheinland Romania [17].
Commercial natural mineral water was used for the infusion's preparation [18] with the following chemical composition (according to the label): Ca^{2+} 40.5 mg·L^{-1}; Mg^{2+} 13.40 mg·L^{-1}; Na^{+} 1.34 mg·L^{-1}; HCO_3^- (bicarbonates) 181 mg·L^{-1}; TDS (total dissolved solids) 132 mg·L^{-1}; *p*H 7.89.
In the first step, the preparation of infusions samples was carried out according to the manufacturer's instructions: one tea bag (2 g) per 200 mL of boiling water (100 ºC) (tea : water ratio 1 : 100 *w/v*) and the brewing time - 10 minutes (Figure 1). The second set of samples was prepared by extending the infusion time from 10 to 15 minutes, in order to observe the influence of brewing time on the analyzed characteristics (sensorial, physico-chemical and phytochemical).
Following the sensorial analysis of the first two sets, based on the suggestions of panelists it was decided to prepare the third set, in which 2 tea bags were used per cup of water (200 mL).
All the variants were prepared in 3 repetitions.

Figure 1. *Samples of red fruit tea infusions*

Sensorial analysis

Sensorial evaluation was carried out through the 7-points hedonic scale method [19]. Appearance, color, aroma, taste, and overall satisfaction of fruit tea infusions were judged.
Fifteen untrained panelists were chosen from the students of the Engineering Faculty ("Vasile Alecsandri" University of Bacău, Romania) according on their interest for this study and their willingness to participate, giving their informed consents.
The participants involved in the hedonic test have received and completed a survey as can be seen in Table 2. The samples were coded from I01 to I05 (first set), I01' to I05' (second set) and I01" to I05" (third set).
Red fruit teas samples were served warm (50 - 55 °C) to the panelists, under white lighting (Figure 2) and all responses were centralized.

Table 2. *Sensorial evaluation for the studied red fruit tea infusions*

<table>
<tr><th rowspan="2">Characteristics</th><th colspan="5">Samples</th><th>Hedonic scale</th></tr>
<tr><th>I01</th><th>I02</th><th>I03</th><th>I04</th><th>I05</th><th rowspan="6">1 – dislike very much
2 – dislike moderately
3 – disliked slightly
4 – neither like nor dislike
5 – like slightly
6 – like moderately
7 – like very much</th></tr>
<tr><td>Appearance</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Color</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Aroma</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Taste</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Overall satisfaction</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Figure 2. *Samples of red fruit tea infusions prepared for the sensorial analysis*

Physical-chemical analyses and phytochemical screening

For each prepared red fruit teas infusion, several physico-chemical parameters, as well as the titratable acidity, the vitamin C content and the color intensity were determined. Table 3 provides details about these analyses, as well as the equipment or method used in the determinations. All measurements were realized in triplicate.

Table 3. *Analyzed parameters for the studied samples of red fruit infusions*

<table>
<tr><th>Parameters</th><th>Equipment used / Method used</th></tr>
<tr><td>pH</td><td rowspan="5">Thermo Scientific™ Orion™ Versa Star Pro™ Multiparameter Benchtop Meter (Thermo Fisher Scientific, USA)</td></tr>
<tr><td>Electrical Conductivity (EC) [$\mu S \cdot cm^{-1}$]</td></tr>
<tr><td>Total Dissolved Solids (TDS) [ppm]</td></tr>
<tr><td>Salinity (SAL) [psu]</td></tr>
<tr><td>Oxidation-Reduction Potential (ORP) [mV]</td></tr>
<tr><td>Titratable Acidity (TA) [%]</td><td>Titrimetric method (using NaOH 0.1 N in the presence of phenolphthalein)*</td></tr>
<tr><td>Total Soluble Solids (TSS) [°Bx]</td><td>Abbe Refractometer (Kruss Optotronik D 22297, Germany)</td></tr>
<tr><td>Color Intensity CI = $A_{420} + A_{520} + A_{620}$ (A_{420}, A_{520}, and A_{620} – absorbance measured at 420 nm, 520 nm, and 620 nm)</td><td>UV-Vis Spectrophotometer (Shimadzu UV-1280, Japan)</td></tr>
<tr><td>Vitamin C content [mg/100 mL]</td><td>Kit for determination of ascorbic acid HI 3850 (Hanna Instruments) and titrimetric method *</td></tr>
</table>

*Analytical grade chemicals were used (Sigma-Aldrich, Merck KGaA, Darmstadt, Germany)

In addition to color intensity, color hue (A_{420} / A_{520}) and the proportion of yellow, red and blue were also calculated for highlighting the contribution of each pigment categories to the expressed color [20].
Also, the studied infusions were subjected to phytochemical examination by UV-Vis scanning between 190 and 1100 nm using an UV-Vis Spectrophotometer (Shimadzu

UV-1280, Japan) in order to offer significant information for differentiating the samples regarding the polyphenolic content.

Statistical analysis

The obtained data were statistically analyzed using the Microsoft EXCEL 2010 Statistical Tool Package. Results were expressed as mean ± standard deviation (SD). Correlations between the parameters were evaluated using Pearson correlation coefficient.
Principal component analysis (PCA) and hierarchical cluster analysis (HCA) were performed using R-Commander 4.3.3. and FactoMineR plugins for multivariate analysis [21] for highlighting the similarities or differences between the samples.

RESULTS AND DISCUSSIONS

Physical-chemical analyses and phytochemical screening

The physico-chemical parameters such as *p*H, EC, TDS, SAL, ORP, TSS and the vitamin C content of the first set of samples obtained according to the manufacturer's instructions are presented in Figure 3 in a multilayer graphical representation.

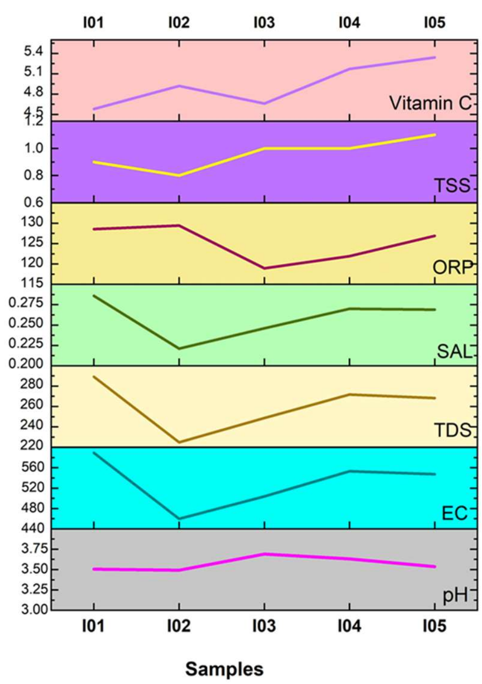

Figure 3. *Measured parameters for the analyzed samples obtained by infusion according to the manufacturer's instructions (1 bag/200 mL water, for 10 minutes)*

The recorded results for titratable acidity, EC, TSD, ORP and TSS for all studied infusions are shown in Table 4.

Table 4. *Analyzed parameters for the studied samples of red fruit infusions*

Samples	Acidity [%]	EC [μS·cm^{-1}]	TDS [ppm]	ORP [mV]	TSS [°Bx]
I01 (1 bag, 10 min)	0.11±0.01	589.50±1.41	289.16±1.07	128.56±0.55	0.90±0.02
I02 (1 bag, 10 min)	0.10±0.01	459.80±4.16	224.70±0.75	129.43±0.32	0.80±0.03
I03 (1 bag, 10 min)	0.10±0.01	503.76±1.18	248.66±1.46	118.90±1.67	1.00±0.01
I04 (1 bag, 10 min)	0.12±0.04	553.26±3.35	271.70±0.20	121.90±0.85	1.00±0.01
I05 (1 bag, 10 min)	0.11±0.03	547.30±1.15	268.23±1.82	126.93±1.01	1.06±0.03
I01 (1 bag, 15 min)	0.16±0.01	578.53±0.23	289.16±1.07	139.83±1.70	0.93±0.01
I02 (1 bag, 15 min)	0.15±0.05	513.43±0.40	252.16±0.15	136.73±1.76	0.86±0.02
I03 (1 bag, 15 min)	0.20±0.01	533.30±0.62	262.30±0.79	140.36±0.75	1.03±0.03
I04 (1 bag, 15 min)	0.16±0.05	515.03±0.75	253.43±1.11	135.50±1.08	1.06±0.01
I05 (1 bag, 15 min)	0.15±0.05	535.96±0.20	262.96±0.23	140.46±1.41	1.10±0.03
I01 (2 bags, 10 min)	0.28±0.02	919.26±2.65	449.60±0.86	188.40±2.19	0.96±0.01
I02 (2 bags, 10 min)	0.15±0.05	803.13±0.77	394.30±1.47	174.73±2.61	0.93±0.02
I03 (2 bags, 10 min)	0.28±0.01	837.36±2.04	410.46±0.11	197.53±0.40	1.06±0.03
I04 (2 bags, 10 min)	0.29±0.01	864.63±0.47	423.43±0.66	177.06±2.25	1.10±0.02
I05 (2 bags, 10 min)	0.29±0.01	815.63±0.45	400.03±0.90	166.13±2.60	1.16±0.01

For a better visualization and comparison between the three investigated sets, the *p*H was graphically represented in Figure 4.

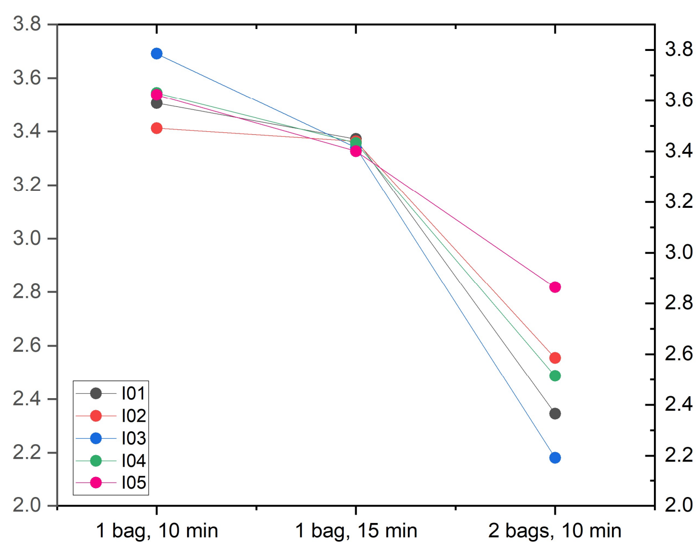

Figure 4. *pH values for the three sets of analyzed samples*

The *p*H values for the first set prepared according to the manufacturer's instructions were slightly acidic ranging from 3.49 (for I02 sample) to 3.69 (for I03 sample). Comparable results with a relatively small increase of *p*H values (3.72 - 4.11) were reported by Flores-Martinez *et al.* [22], in their study related to ready-to-drink flavored-colored commercial teas, but the composition of teas is quite different. Also, data reported by Lunkes and Hashizume [23] showed lower *p*H values (2.89 - 3.41) for some teas commercially available in Brazil. The *p*H of the fruit teas after 10 minutes of infusion ranged between 2.73 and 3.59 in the study of Akyuz and Yarat [24]. The lower *p*H values could be attributed to orange or lemon peels found in the fruit teas studied by the Turkish authors [24] or due to the acidifiers used such as citric acid or malic acid [23].

In the case of the second set of samples when the infusion time was increased from 10 to 15 minutes, only a small decrease in *p*H is observed compared to the values recorded in the first set of samples (3.32-3.43) as it can be seen in the Figure 4.

A rather large decrease occurs in the case of the third set of samples, when using two tea bags per 200 mL of water at an infusion time of 10 minutes.

The same trend was observed in the case of titratable acidity, with values ranging between 0.103 and 0.116 % in the case of first set samples, increasing to values of 0.270-0.290 % in the third batch (Table 3). Titratable acidity from 0.092 to 0.174 % and 0.193 to 0.325 %, respectively were reported in the previously mentioned studies [22, 23].

Oxidation-Reduction Potential is usually inverse related to *p*H [19]. So, when beverages are acidic and have low *p*H values, the ORP increases to high positive values. For example, in their study, Tan *et al.* [19] reported that drinking waters (mineral or tap water) with a *p*H values of 6.49 - 6.63, may present ORP values higher than +180 mV. Alkaline water with a high *p*H of 8.64 has lower ORP values (94 mV). In our study, the ORP values of the red fruits tea infusions are ranging from +118.90 to 197.50 mV, even the *p*H is quite acidic (Table 3). The results of measurements obtained for the analyzed infusions represent good ORP values, confirming that due to their content in polyphenolic compounds, the infusion present antioxidant properties.

Concerning the total soluble solids which represent the amounts of extractable substances, our results showed an irrelevant augmentation both with the increase of infusion time (second set) and the amount of tea subjected to infusion (third set). TSS values (0.86 - 1.16 °Bx) are similar, slightly higher than those reported by Tan *et al.* [19] for green tea infusions (0.70 - 0.97 °Bx).

The vitamin C amount of studied infusions is presented in Figure 5.

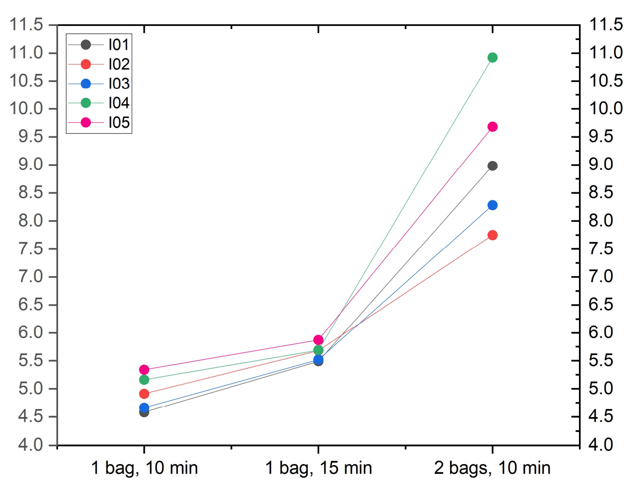

Figure 5. *Vitamin C content [mg/100 mL] of fruit tea samples*

It is well known that the red fruits represent a good source of ascorbic acid, a water soluble vitamin [10]. The vitamin C content of infusions may vary depending on the preparation method (brewing time and temperature) and tea ingredients [10].
For the first set of infusions, the highest content of ascorbic acid can be observed in the samples containing 23 % red fruits (5.16 mg/100 mL for I04 and 5.34 mg/100 mL for I05). A very slight increase of vitamin C content was observed when the brewing time is longer (15 minutes), the biggest value being detected in sample I01 (5.87 mg/100 mL) with 28 % more than the similar sample infused for 10 minutes (4.58 mg/100 mL).
As expected, the amount of vitamin C is proportional to the quantity of red fruits subjected to infusion, when using two sachets, the content doubling in almost all samples. Infusion I04 obtained is notable for its vitamin C content of 10.92 mg/100 mL.
Color represents a significant characteristic of beverages and plays an important role in judging their quality, frequently predetermining consumer expectation [22]. Moreover, color can influence the perception of aroma or flavor [25].
Many fruits such as strawberries, cherries, black currants, blackberries, blueberries, etc. are very rich in anthocyanins. These pigments that are soluble in water contribute to the red, blue, and purple color of beverages obtained from red fruits [25].
The color intensity (CI) of red fruit tea samples was evaluated by summing the absorbance values measured at 420, 520 and 620 nm, respectively (Figure 6).

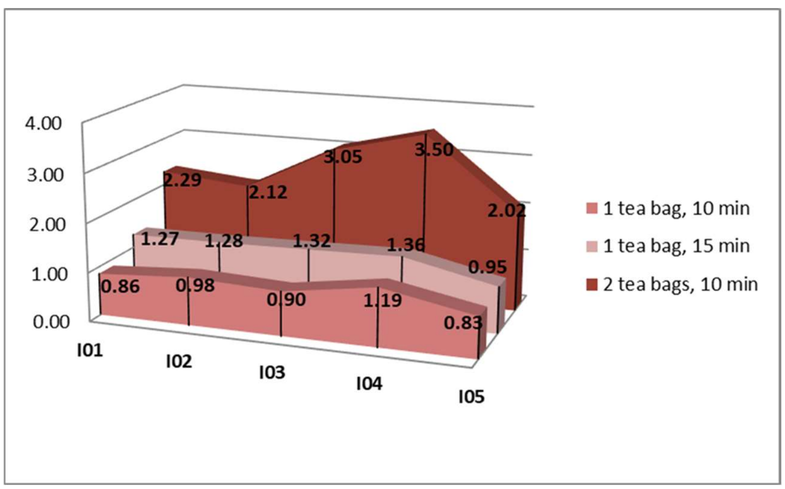

Figure 6. *Color intensity of red fruit teas infusions*

Also, the color hue and the proportion of yellow, red and blue were calculated and the results are presented in Table 5.
As can be seen from Figure 6, the samples with the highest CI values from the three infusion sets are those from forest fruits (I04): 1.19 in the case of sample obtained using 1 tea bag and infused for 10 minutes, 1.37 for the sample infused for 15 minutes and 3.50 for the infusion obtained using 2 bags and infused 10 minutes. This infusion also stood out for its highest value of the proportion of red (57.87 %).
Thus, extending the infusion time from 10 to 15 minutes leads to an increase in CI by approximatively 14 % (I04 and I05), 30 % (I02) and 48 % (I01 and I03), showing that the extraction of the pigments responsible for the coloring of the infusions is not complete after the 10 minutes.

__Table 5.__ Color parameters of all analyzed samples

Samples	Color intensity	Color hue	Proportion of yellow [%]	Proportion of red [%]	Proportion of blue [%]
I01 (1 bag, 10 min)	0.86±0.03	0.84±0.02	41.14±0.01	49.18±0.02	9.67±0.03
I02 (1 bag, 10 min)	0.98±0.03	083±0.03	41.97±0.02	50.31±0.02	7.72±0.03
I03 (1 bag, 10 min)	0.90±0.02	0.89±0.02	42.91±0.03	48.38±0.03	8.72±0.02
I04 (1 bag, 10 min)	1.19±0.01	0.87±0.01	41.40±0.02	47.64±0.02	10.96±0.01
I05 (1 bag, 10 min)	0.83±0.01	0.77±0.01	38.61±0.02	49.88±0.01	11.51±0.01
I01 (1 bag, 15 min)	1.27±0.01	0.83±0.02	39.17±0.01	46.94±0.01	13.89±0.02
I02 (1 bag, 15 min)	1.28±0.02	0.88±0.03	40.11±0.03	45.41±0.02	14.49±0.03
I03 (1 bag, 15 min)	1.32±0.05	0.79±0.04	39.71±0.04	50.38±0.03	9.91±0.03
I04 (1 bag, 15 min)	1.36±0.04	0.87±0.03	41.26±0.03	47.36±0.03	11.38±0.02
I05 (1 bag, 15 min)	0.95±0.05	0.81±0.02	40.50±0.02	49.74±0.02	9.76±0.03
I01 (2 bags, 10 min)	2.29±0.04	0.63±0.03	35.04±0.02	55.64±0.02	9.32±0.02
I02 (2 bags, 10 min)	2.12±0.05	0.64±0.04	35.60±0.03	55.29±0.03	9.11±0.01
I03 (2 bags, 10 min)	3.05±0.01	0.60±0.01	34.44±0.02	57.49±0.01	8.07±0.01
I04 (2 bags, 10 min)	3.50±0.02	0.58±0.02	33.73±0.01	57.87±0.01	8.40±0.02
I05 (2 bags, 10 min)	2.02±0.01	0.62±0.02	34.99±0.01	56.77±0.02	8.24±0.02

Even though the use of two tea bags for the preparation of infusions should have doubled the color intensity, a remarkable increase in CI was observed, with values 2.2 - 3.4 times higher than those obtained from a single bag.

Principal component analysis (PCA) and hierarchical cluster analysis (HCA) were performed for analyzing the dataset color parameters for all red fruits infusions (15 samples, 5 variables: color intensity, color hue, proportion of yellow, proportion of red and proportion of blue).

The PCA graph from Figure 7 shows correlations among the variables. The results of PCA are in excellent agreement with the Pearson correlation coefficients (data not shown).

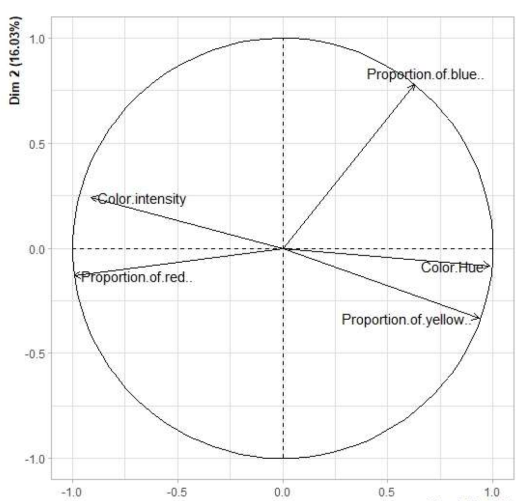

***Figure 7.** The PCA graph of variables related to analyzed color parameters*

Thus, as can be seen in the left quadrant, the color intensity of samples and proportion of red had close angle, which means that these variables were correlated. This is in accordance with the high value of Pearson correlation coefficient (0.84). The hue of the color and the proportion of yellow are very strongly correlated, as they are found in the same quadrant and the angle between them is very tight. Indeed, the Pearson coefficient has a value very close to 1 (0.96). A moderate correlation between the proportion of blue and the color hue is revealed also by a correlation coefficient of 0.55.

The factor map resulting from the application of HCA allows to see differences and similarities among the samples (Figure 8). The fifteen analyzed infusions were split into three clusters (black, green and red). It can be observed that, from the point of view of the five color parameters analyzed, the cluster 1 containing the samples obtained by infusion of two bags for 10 minutes are more confined than all the other samples (black circle in Figure 8). These samples are positioned far from the others. Cluster 2 (in red) contains eight of the fifteen samples, with CI values between 0.86 and 1.36, and red proportion values between 47.36 and 50.38 %. Cluster 3 (in green) comprises only two samples, namely I01 and I02 obtained from a tea bag with an infusion time of 15 minutes, these being characterized by the lowest values of the proportion of red (45.41 and 46.94 %) and the highest values of the proportion of blue (13.89 and 14.49 %).

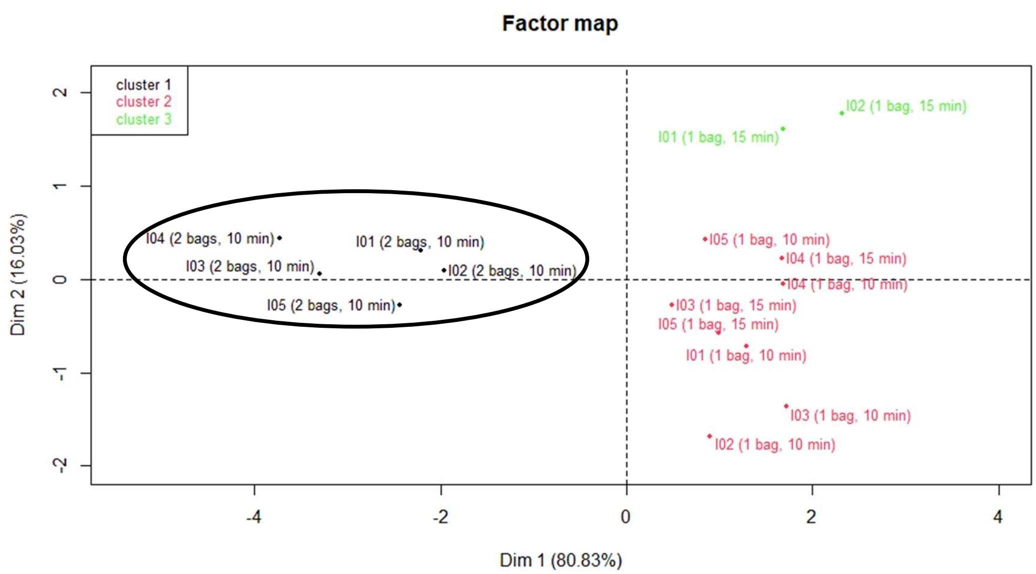

Figure 8. *The HCA factor map related to color parameters*

UV-Vis spectrophotometric screening has proven to be suitable for identifying the presence and concentration of different categories of compounds such as phenolic molecules found in the plant-based extracts. Thus, by analyzing the spectra of different extracts, comparisons can be made providing information about the amounts of bioactive compounds [26 – 30].

The overlapped UV-Vis spectra for the first and third set of infusions samples are presented in Figure 9. The largest and most important absorption bands were observed from 250 to 330 nm associated with the adsorption of flavonoid compounds such as flavonol aglycons (e.g., myricetin, quercetin), hydroxycinnamic acids (e.g., rosmarinic acid, chlorogenic acid) and a part of the anthocyanins. Indeed, such phenolic compounds in fruit tea infusion (at water temperature of 100 °C) have been quantified by Şahin [2], by using HPLC-PDA (high performance liquid chromatography with photodiode array detection).

The band observed at 515-530 nm is due to the anthocyanin content such as cyanidin-3-glucoside and pelargonidin-3-glucoside, as it is described recently by Liu *et al.* [31].

Taking into account the height of the bands, respectively the value of the absorbance corresponding to the wavelength from 510 to 530 nm, it can be seen that, the samples obtained from two tea bags have a more than double anthocyanin content, which is in accordance with the values of the color intensity.

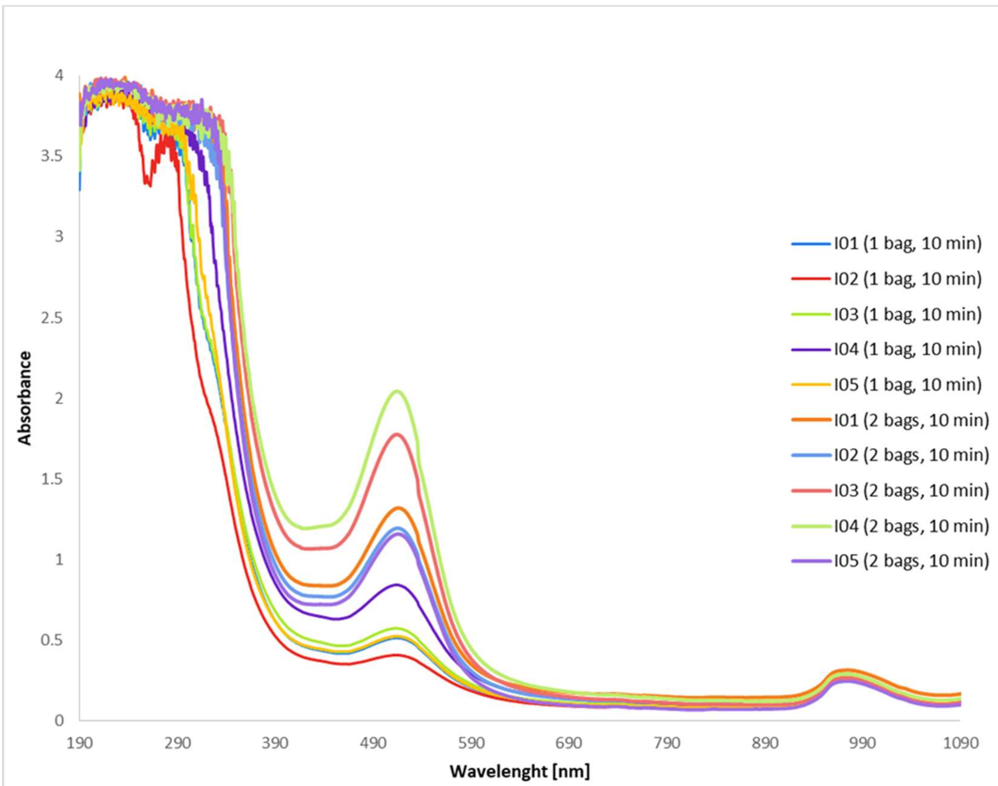

Figure 9. *UV-Vis spectra of red fruit teas infusions*

Sensorial analysis of red fruits tea infusions

The aspect, color, taste, aroma, and the degree of global satisfaction were evaluated in terms of consumer preference.

As it was mentioned in the section regarding the preparation of samples, following the sensorial analysis of the first two sets (with a score for the global satisfaction between 4.7 and 5.9) and based on the suggestions of panelists, it was decided to prepare the third set, in which two tea bags were used per cup of water (200 mL).

According to Figure 10, overall satisfaction increased as the infusion time went from 10 minutes to 15 minutes. The most noticeable increase was perceived in the case of I02

sample, from an overall score of 4.7 attended after 10 minutes of infusion to 5.7 after 15 minutes. The smallest increase was observed in the case of I04 and I05 infusions which were rated with a score of only 0.1 points higher than the samples obtained after 10 minutes of infusion.
However, the highest average scores (6.0 - 6.8) were achieved for the third set, when two tea bags were used and infused for 10 minutes. The highest degree of global satisfaction was obtained by sample I05, recording a significant increase from 5.6 - 5.7 to 6.8, followed by I04 with a score of 6.5 and I03 with a score of 6.2. It is known that the best-received infusions by consumers are those with a higher content of chemical constituents (e.g., flavonoids, phenolic acids, anthocyanins, etc.) [19].

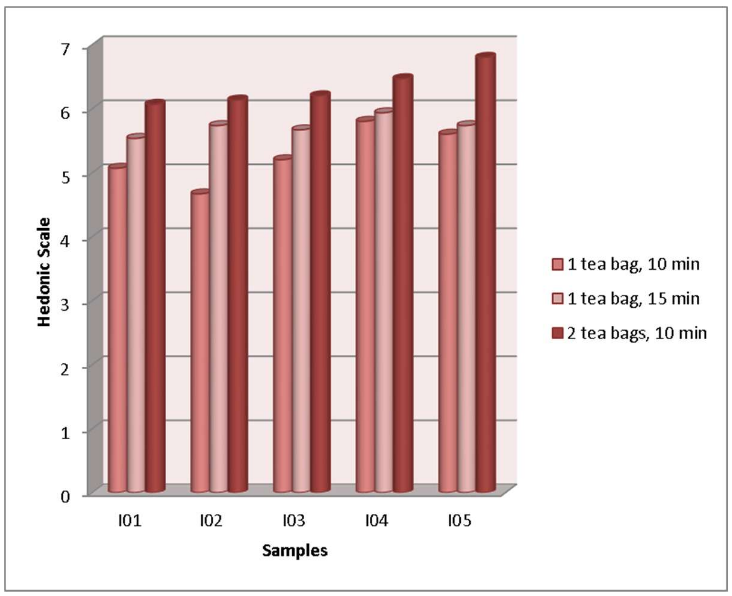

Figure 10. *Overall satisfaction of red fruits tea infusions*

The radar graph of analyzed organoleptic properties (aspect, color, taste, aroma) of samples I04 and I05 from the third set with the best overall satisfaction score are presented in Figure 11.

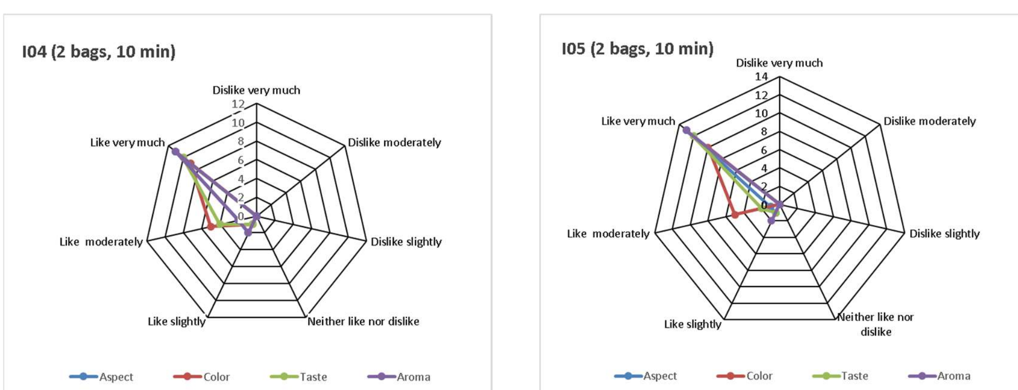

Figure 11. *Radar graphs for I04 and I05 samples from the third set*

CONCLUSIONS

Knowledge of the physico-chemical characteristics, phytochemical and sensorial profile of red fruit teas, depending on various parameters, is an important aspect due to the increased interest of consumers for these types of products presenting an attractive taste and health beneficial properties.

The results highlighted the influence of brewing time, and the proportion of red fruit tea and water used in their preparation, on the quality of the infusions and, respectively, on the overall acceptance. Following the recording of the global degree of appreciation, the infusions I04 and I05 (2 bags, 10 minutes) were most preferred by consumers.

Our research revealed that the brewing time for red fruits tea infusions recommended by the manufacturer (10 minutes) does not seem to be enough in order to obtain an infusion with the maximum level of customer satisfaction.

Therefore, extending the brewing time to 15 minutes or using two bags instead of one bag for the same quantity of water, conduct to infusions with higher content of bioactive compounds which is reflected in a greater intensity of color and proportion of red in the samples. The content of vitamin C and phytochemical profile are correlated with the degree of global satisfaction.

The results obtained in the present work provide valuable information to consumers about red fruits tea infusions based on the physico-chemical, phytochemical and sensorial characteristics, which can contribute to the knowledge and selections of red fruits teas by the consumers.

REFERENCES

1. Moldovan, B., Hosu, A., David, L., Cimpoiu, C.: Total phenolics, total anthocyanins, antioxidant and pro-oxidant activity of some red fruits teas, *Acta Chimica Slovenica*, **2016**, **63** (2), 213-219;
2. Şahin, S.: Evaluation of antioxidant properties and phenolic composition of fruit tea infusions, *Antioxidants*, **2013, 2** (4), 206-215; https://doi.org/10.3390/antiox2040206
3. Šavikin, K., Zdunić, G., Janković, T., Gođevac, D., Stanojković, T., Pljevljakušić, D.: Berry fruit teas: Phenolic composition and cytotoxic activity, *Food Research International*, **2014**, **62**, 677-683; http://dx.doi.org/10.1016/j.foodres.2014.04.017
4. Zieniewska, I., Zalewska, A., Zendzian-Piotrowska, M., Ładny, J.R., Maciejczyk, M.; Antioxidant and antiglycation properties of seventeen fruit teas obtained from one manufacturer, *Applied Science*, **2020**, **10** (15), 5195; https://doi.org/10.3390/app10155195
5. Pękal, A., Dróżdż, P., Biesaga, M., Pyrzynska, K.: Evaluation of the antioxidant properties of fruit and flavoured black teas, *European Journal of Nutrition*, **2011**, **50** (8), 681-688; https://doi.org/10.1007/s00394-011-0179-2
6. Winiarska-Mieczan, A., Baranowska-Wójcik, E.: The effect of brewing time on the antioxidant activity of tea infusions, *Applied Science*, **2024**, **14** (5), 2014; https://doi.org/10.3390/app14052014
7. Bratu, M.M., Birghila, S., Popescu, A., Negreanu-Pirjol, B.S., Negreanu-Pirjol T.: Correlation of antioxidant activity of dried berry infusions with the polyphenols and selected microelements contents, *Bulletin of the Chemical Society of Ethiopia*, **2018**, **32** (1), 1-12; https://dx.doi.org/10.4314/bcse.v32i1.1
8. Chilczuk, B., Materska, M., Staszowska-Karkut, M., Pabich, M.: The effect of enriching tea infusion with fruit additives on their antioxidant properties and the profile of bioactive compounds, *Applied Sciences,* **2025**, **15**, 316; https://doi.org/10.3390/app15010316
9. Hidalgo, G.-I., Almajano, M.P.: Red fruits: extraction of antioxidants, phenolic content, and radical scavenging determination: A review, *Antioxidants*, **2017**, **6** (1), 7; https://doi.org/10.3390/antiox6010007

10. Bortolini, D.G., Maciel, G.M., Fernandes, I.D.A.A, Rossetto, R., Brugnari, T., Ribeiro, V.R., Haminiuk, C.W.I.: Biological potential and technological applications of red fruits: An overview, *Food Chemistry Advances*, **2022**, **1**, 100014; https://doi.org/10.1016/j.focha.2022.100014
11. Cosme, F., Pinto, T., Aires, A., Morais, M.C., Bacelar, E., Anjos, R., Ferreira-Cardoso, J., Oliveira, I., Vilela, A., Gonçalves, B.: Red fruits composition and their health benefits-A review, *Foods*, **2022**, **11** (5), 644; https://doi.org/10.3390/foods11050644
12. David, L., Hosu, A., Moldovan, B., Cimpoiu, C.: Evaluation and authentication of red fruits teas by high performance thin-layer chromatographic fingerprinting, *Journal of Liquid Chromatography & Related Technologies*, **2014**, **37** (12), 1644-1653; https://doi.org/10.1080/10826076.2013.803206
13. https://fares.ro/produse/ceaiuri-din-fructe/, accessed April 26, 2024;
14. https://fares.ro/despre-calitatea-plantelor/, accessed April 26, 2024;
15. ****: ISO 22000:2018 - Food Safety Management Systems—Requirements for Any Organization in the Food Chain*, 2nd edition, ISO, Geneva, Switzerland, **2018**, p. 37;
16. ****: ISO 9001:2015 - Quality Management Systems-Requirements*, ISO, Geneva, Switzerland, **2015**.
17. https://www.tuv.com/romania/ro/, accessed May 03, 2024;
18. https://aquacarpatica.ro/, accessed April 26, 2024;
19. Tan, H.L., Ojukwu, M., Lee, L.X., Mat Easa, A.: Quality characteristics of green Tea's infusion as influenced by brands and types of brewing water, *Heliyon*, **2022**, **9** (2), e12638; https://doi.org/10.1016/j.heliyon.2022.e12638
20. Teneva, D., Pencheva, D., Petrova, A., Ognyanov, M., Georgiev, Y., Denev, P.: Addition of medicinal plants increases antioxidant activity, color, and anthocyanin stability of black chokeberry (*Aronia melanocarpa*) functional beverages, *Plants*, **2022**, **11** (3), 243; https://doi.org/10.3390/plants11030243
21. FactoMineR: Exploratory Multivariate Data Analysis with R. Available online: http://factominer.free.fr/ (accessed on 10 May 2024)
22. Flores-Martínez, D., Urías-Orona, V., Hernández-García, L., Rubio-Carrasco, W., Silva-Gutiérrez, K., Guevara-Zambrano, M., Prieto-Cadena, J., Serna-Méndez, T., Muy-Rangel, D., Niño-Medina, G.: Physicochemical parameters, mineral composition, and nutraceutical properties of ready-to-drink flavored-colored commercial teas, *Journal of Chemistry*, **2018**, 2861541; https://doi.org/10.1155/2018/2861541
23. Lunkes, L.B.F., Hashizume, L.N.: Evaluation of the pH and titratable acidity of teas commercially available in Brazilian market, *RGO - Revista Gaúcha de Odontologia*, **2014**, **62** (1), 59-64; https://doi.org/10.1590/1981-8637201400010000092623
24. Akyuz, S., Yarat, A.: The pH and neutralisable acidity of the most-consumed Turkish fruit and herbal teas, *Oral Health and Dental Management*, **2010**, **IX** (2), 75-78;
25. Vilela, A.; Cosme, F.: Drink red: Phenolic composition of red fruit juices and their sensorial acceptance, *Beverages*, **2016**, **2** (4), 29; https://doi.org/10.3390/beverages2040029
26. Guemari, F., Laouini, S.E., Rebiai, A., Bouafia, A., Meneceur, S., Tliba, A., Majrashi, K.A., Alshareef, S.A., Menaa, F., Barhoum, A.: UV-Visible spectroscopic technique-data mining tool as a reliable, fast, and cost-effective method for the prediction of total polyphenol contents: Validation in a bunch of medicinal plant extracts, *Applied Sciences*, **2022**, **12** (19), 9430; https://doi.org/10.3390/app12199430
27. Giusti, M.M., Wrolstad, R.E.: Characterization and measurement of anthocyanins by UV-visible spectroscopy, *Current Protocols in Food Analytical Chemistry*, **2001**, F1.2.1-F1.2.13; https://doi.org/10.1002/0471142913.faf0102s00
28. Loum, J., Byamukama, R., Wanyama, P.A.G.: UV-Vis spectrometry for quantitative study of tannin and flavonoid rich dyes from plant sources, *Chemistry Africa*, **2020**, **3** (8), 449-455; https://doi.org/10.1007/s42250-020-00135-6
29. Jansom, C., Bhamarapravati, S., Itharat, A.: Major anthocyanin from ripe berries of *Cleistocalyx nervosum* var. paniala, *Thammasat Medical Journal*, **2008**, **8** (3), 364-370;
30. Petenatti, M.E., Gette, M.A., Camí, G.E., Popovich, M.C., Marchevsky, E.J., Del Vitto, L.A., Petenatti, E.M.: Quantitative micrograph, HPLC and FTIR profiles of *Melissa officinalis* and *Nepeta cataria* (Lamiaceae) from Argentina, *Revista de la Facultad de Ciencias Agrarias*, **2014**, **46** (2), 15-27;

31. Liu, S., Zhang, Y.: Antioxidant properties and electrochemical activity of anthocyanins and anthocyanidins in mulberries, *Journal of Food Measurement and Characterization*, **2024**, **18** (5), 3569-3576; https://doi.org/10.1007/s11694-024-02426-9