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A COMPARATIVE GRAVIMETRIC STUDY ON SOME FRUIT TEA ASSORTMENTS

Dariana-Alexia CRAȘOVAN[1], Ioana-Maria TOPLICEAN[1,*], Adina-Daniela IACHIMOV-DATCU[1]

[1]Department of Biology, Faculty of Chemistry, Biology, Geography, West University of Timisoara, Pestalozzi 16, 300115, Timişoara, Romania

**Corresponding author's e-mail: ioana.toplicean03@e-uvt.ro*

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ABSTRACT

Fruit tea is a common beverage worldwide, being produced using different parts of various plant species. The aim of this investigation is to perform a comparative analysis of tea assortments containing rosehip (Cynosbati fructus) and Hibiscus (Hibiscus sabdariffa), focusing on their initial water content, relative humidity, and dry matter. For each tea type, multiple samples were analyzed by determining weights, which led to the calculation of quality indicators. Statistical analyses were performed to compare the tea varieties, revealing significant differences among the investigated indices. Variations were attributed to differences in ingredient composition, processing methods, and packaging conditions. Teas with higher dry matter content were associated with greater phytochemical concentration and enhanced stability, while those with higher water content showed potential for faster quality degradation. The results provide valuable insights for quality control, shelf-life assessment, and technological evaluation of fruit and herbal teas.

KEY WORDS: *fruit tea, dry matter, relative humidity, phytochemical content*

INTRODUCTION

Tea is one of the staple beverages worldwide, being appreciated not only for its pleasant aroma and flavor but also for its numerous bioactive compounds with antioxidant and health-promoting properties (Sharangi, 2009). The difference between the composition and quality of teas generally influences the organoleptic characteristics and the content of bioactive compounds (Tolić *et al.* 2015). Fruit teas, also known as herbal infusions, are prepared from dried fruits, sometimes combined with peels, flowers, or other plant parts, and do not typically contain *Camellia sinensis* leaves. Frequently used fruits include strawberry, apple, peach, pomegranate, blueberry, blackberry, and citrus (Varga & Pintér, 2012). Hibiscus (*Hibiscus sabdariffa*) and rosehip (*Rosa canina*) are often utilized for their bright color, antioxidant content, and health-promoting properties (Chrubasik *et al.* 2008; Hopkins *et al.* 2013). Fruit teas are rich in various types of bioactive compounds, such as polyphenols, flavonoids, anthocyanins, vitamins, minerals, organic acids, and other constituents that contribute to their antioxidant, immunostimulatory, anti-inflammatory and metabolic benefits (Tariq *et al.* 2010; Varga & Pintér, 2012; Šavikin *et al.* 2014). Rutin, catechins, chlorogenic acid, and hesperidin are among the major phenolic compounds, while anthocyanins from berries contribute to color and potential neuroprotective and cardiovascular effects (Şahin, 2013; Sivakumaran & Amarakoon, 2017).

The physicochemical properties of fruit teas can vary considerably depending on multiple factors, such as origin, processing, and the type of ingredients used (Kika *et al.* 2024; Sharma & Dutta, 2023). Therefore, the evaluation of their dry matter content through gravimetric analysis provides essential information for comparing their potential nutritive and functional properties (Kaur *et al.* 2015). Gravimetric analysis, one of the oldest and most reliable analytical techniques, plays a crucial role in assessing the total solid content of various plant-based products. The fraction of the fruit mass, excluding water, is represented by dry matter and is related to quality attributes, such as soluble solids (Scalisi & O`Connell, 2021). In the case of tea infusions, determining the dry residue allows for the estimation of soluble compounds extracted during brewing, reflecting both the concentration of active substances and the overall quality of the product (Armoskaite *et al.* 2011). The oxidation of polyphenols, the rate of chemical reactions, their physical stability and susceptibility to microbial growth are directly influenced by the moisture content of the leaves (Zhang *et al.* 2025). This parameter can therefore serve as an indirect indicator of the tea's nutritive and functional potential.

There is a growing trend in analyzing the possible tea waste disposal solutions (Lubura Stošić *et al*. 2025) and some researchers suggested its utility in Cu and Pb decontamination of water (Amarasinghe & Williams, 2007) or for hydrogen production (Ayas & Esen, 2016).

The aim of this study is to comparatively analyze several fruit tea assortments using the gravimetric method, in order to determine their total soluble solid content and assess differences related to their composition and quality.

MATERIALS AND METHODS

Five tea assortments were purchased from Timișoara, Romania and laboratory testing was conducted in September 2025. The analyzed products were labeled and can be described as follows: Sample I consisted of tea purchased in bulk at a price of 3.35 RON for 75g. The listed ingredients were rosehip (*Cynosbati fructus*) 52,8% and Hibiscus (*Hibiscus sabdariffa*) 47,2 %.

Sample II was available in teabags and was priced at 4.47 RON for 30g. The tea includes Hibiscus flowers (*Hibiscus sabdariffa*), a blend of variable proportions of rosehip (*Cynosbati fructus*) pulp and seeds, wild apple fruits (*Malus sylvestris*), wild strawberry (*Fragaria vesca*) and blackberry (*Rubus spp.*) leaves, different flavors.

Sample III was represented in teabags, with a price of 5.06 RON for a quantity of 81.25g. According to the label, it contains 51% rosehip (*Cynosbati fructus*), 30% Hibiscus (*Hibiscus sabdariffa*), 12% chokeberries (*Aronia melanocarpa*), 7% apples (*Malus domestica*).

The next, Sample IV, was in the form of teabags and was sold at 10.47 RON per 40g. It contains 65% rosehip (*Cynosbati fructus*) and 35% Hibiscus (*Hibiscus sabdariffa*).

The last product, described as Sample V, was purchased in bulk, at 14.14 RON for 80g of product. The tea includes ingredients such as apple (*Malus domestica*), rosehip (*Cynosbati fructus*), raisins (*Vitis vinifera*), hibiscus (*Hibiscus sabdariffa)*, cranberries (*Vaccinium oxycoccos*), lemon grass (*Cymbopogon citratus*), orange peel (*Citrus* × *sinensis*), flavors, strawberries and strawberry leaves (*Fragaria* × *ananassa*).

Ten samples of each analyzed type were placed in paper envelopes and their fresh weight was determined by weighing them on an analytical balance (OHAUS model). The samples were then placed in an oven at 100 degrees Celsius for complete drying and then reweighed to determine their dry weight. The indices analyzed were the initial water quantity, the relative humidity of the samples, and the percentage of dry matter, according to the formulas:

1. Initial water content (IWQ, g)

$$IWQ = FW - DW \quad (1)$$

2. Relative humidity (H, %)

$$H\% = \frac{FW - DW}{FW} \times 100 \quad (2)$$

3. Dry matter (DM, %)

$$DM\ (\%) = \frac{DW}{FW} \times 100 \quad (3)$$

Statistical analysis was performed using PAST 5.2.2. (Hammer et al. 2001). The Shapiro-Wilk test was used to notice whether the samples had a normal distribution. Testing continued with Kruskal Wallis (KW) for equal medians, supplemented by Mann-Whitney U, with Bonferroni correction.

RESULTS AND DISCUSSIONS

The initial water content is an indicator that illustrates how much water the product contains and for its determination complete dehydration is necessary. It represents an important parameter for the preservation, stability and quality of the product. IWQ values vary depending on the raw material, packaging and storage conditions.

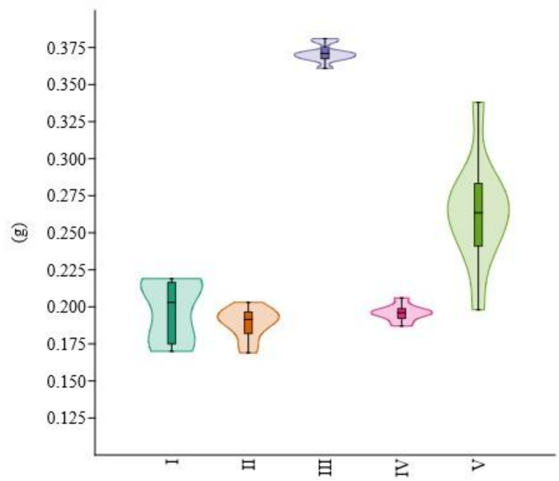

FIG. 1. IWQ variation for the five analyzed tea assortments

In figure 1, the variation of IWQ among tea varieties can be observed. A minimum value was highlighted for sample II, and a maximum value for sample III. This sample also had the highest minimum value of all the samples, indicating a considerably higher amount of IWQ than the rest. For sample I, the distribution of values was between a minimum of 0.170 g and a maximum of 0.219 g.

For sample II, the distribution of values tends to be towards the max point, 0.203 g, with much fewer values being towards the minimum point, 0.169 g.

The highest values for this index were identified for the third sample. Here, a min of 0.361 g and a maximum of 0.381 g were calculated, and the distribution of values was more widely distributed around the mean. A similar distribution is displayed in sample IV, where the minimum value was 0.187 g, and the maximum point was 0.206 g. In sample V, a wider variation was observed between the minimum point (0.198 g) and the maximum point (0.338 g), the distribution of values being more uniform but still centered around the mean.

Shapiro-Wilk test results for the initial water quantity were revealed in Table 1. All the samples, except for the first, presented a normal distribution. Based on these findings, a further KW test was needed, because not all data follow a normal distribution.

TABLE 1. Shapiro-Wilk results for IWQ

IWQ (g)	I	II	III	IV	V
Shapiro-Wilk W	0.8376	0.9416	0.9427	0.9785	0.9436
p(normal)	0.0413	0.5709	0.6102	0.9569	0.5936

After testing the normal distribution of the data, the KW test was applied for equal medians. The results of this test were H (chi^2): 35.44 and p = 0.00000037, meaning that there is a significant difference between sample medians. This result confirms that the tea varieties differ significantly in water content.

Based on these findings, the result from KW, we continued with the Mann-Whitney U test, with the Bonferroni correction, that can be seen in Table 2. The test revealed significant differences ($p < 0.05$) between most samples, especially between sample III and the others in the same situation, including sample V.

TABLE 2. Mann-Whitney U results for IWQ

IWQ (g)	I	II	III	IV	V
I		1.00000	0.00276	1.00000	0.00765
II	1.00000		0.00278	1.00000	0.00284
III	0.00276	0.00278		0.00275	0.00278
IV	1.00000	1.00000	0.00275		0.00375
V	0.00765	0.00284	0.00278	0.00375	

A higher initial amount of water may come from fruit that has been insufficiently dehydrated (Bhattacharjee *et al.* 2024).

As an indicator of the technological and commercial quality of a product, relative humidity (H%) expresses the percentage of water relative to the total mass of the fresh sample. As shown in Figure 2, which is a violin type graph, humidity levels varied among samples. The minimum point was noticed at sample IV (9.126%) and the maximum point at sample I (17.992%).

For sample I in the range of humidity was between min = 15.385% and max = 17.992%, with a larger distribution of values towards the mean and min side. For sample II, where minimum point of humidity was 11.191% and maximum was 12.197%. Humidity of sample III had a minimum value of 9.153% and a maximum value of 9.497%. An inverse distribution of values (around the mean area, in the max side) was noticed at sample IV, where min is 9.126% and max is 10.213%. For sample V the minimum point of humidity index was 9.817% and the biggest humidity value was 10.826%.

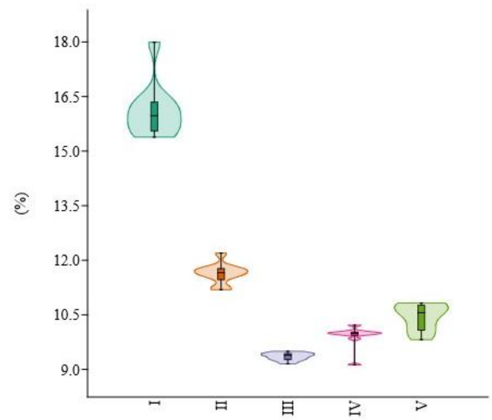

FIG. 2. Humidity (%) variation for the five analyzed tea assortments

In table 3 the result of the Shapiro-Wilk test for H (%) is expressed. It shows a non-normal distribution for samples I and IV, with $p < 0.05$. Given the outcomes, a further KW test was applied, because the data does not follow a normal distribution.

TABLE 3. Shapiro-Wilk test for H (%)

H(%)	I	II	III	IV	V
Shapiro-Wilk W	0.8242	0.9237	0.9573	0.6616	0.8788
p(normal)	0.0285	0.3889	0.7694	0.0003	0.1524

After testing the normal distribution of the data, the KW test was applied for equal medians. The results are as follows: H (chi^2): 43.2200 and p (same): 0.000000009. There is a significant difference between the sample medians. This confirms that the tea varieties differ significantly in humidity content.

As indicated by the results from KW, we continued with the Mann-Whitney U test, with the Bonferroni correction and the results highlighted in Table 4. The test revealed significant differences ($p < 0.05$) for most samples, except for samples IV and V, where p = 0.079630.

TABLE 4. Mann-Whitney U test for H (%)

H(%)	I	II	III	IV	V
I		0.001827	0.002797	0.001827	0.002797
II	0.001827		0.002797	0.001827	0.002797
III	0.002797	0.002797		0.037490	0.004123
IV	0.001827	0.001827	0.037490		0.079630
V	0.002797	0.002797	0.004123	0.079630	

Samples with lower humidity content have increased stability but may exhibit reduced aromatic intensity as excessive drying can lead to the reduction of certain compounds. The ones with higher humidity content may be subject to loss of quality and degradation (Jin *et al.* 2023).

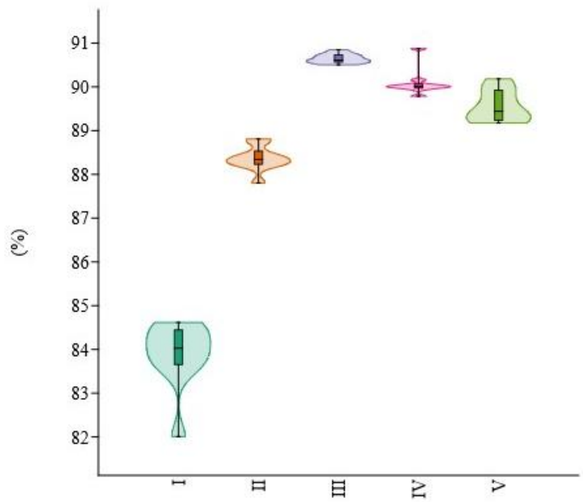

FIG. 3. DM (%) variation for the five analyzed tea assortments

An indicator inversely proportional to relative humidity which reflects the nutritional and aromatic density of the product is represented by the value of dry matter (DM%). It indicates the percentage of solid material remaining after complete removal of water.

In figure 3, the dry matter content in the analyzed samples can be noticed. The minimum value of this parameter was recorded for sample I (82.008%) and the biggest value was calculated for sample IV (90.874%). For sample I, a distribution of values around the mean and max area can be remarked in the min (82.008) -max (84.615%) range. The distribution of values for sample II is also around the mean, with a minimum value of 87.803% and a maximum of 88.809%. For sample III, the minimum was 90.503% and the max was 90.847. For the fourth sample, data varied between 89.787% and 90.874%. For sample V, a min (82.403%) - max (90.183%) interval was established, with a distribution of values more predominant towards the min.

In table 5, the results of the Shapiro-Wilk test for DM (%) were revealed. It reveals a non-normal distribution for the first and the fourth samples, with $p < 0.05$.

Based on the results obtained, a further KW test was needed, because the data does not follow a normal distribution.

TABLE 5. Shapiro-Wilk W test for DM (%)

DM (%)	I	II	III	IV	V
Shapiro-Wilk W	0.8242	0.9237	0.9573	0.6616	0.8788
p(normal)	0.0285	0.3889	0.7694	0.0003	0.1524

KW test results in this case were: H (chi^2): 43.22 and p = 0.000000009. There is a significant difference between sample medians. This confirms that the tea varieties differ significantly in a large proportion of dry matter.

After the results from KW, we continued with the Mann-Whitney U test, with the Bonferroni correction that can be seen in Table 6. The test revealed significant differences ($p < 0.005$) for most samples, except for samples IV and V, which are not significantly different.

TABLE 6. Mann-Whitney U test for DM (%)

	I	II	III	IV	V
I		0.001827	0.002797	0.001827	0.002797
II	0.001827		0.002797	0.001827	0.002797
III	0.002797	0.002797		0.037490	0.004123
IV	0.001827	0.001827	0.037490		0.079630
V	0.002797	0.002797	0.004123	0.079630	

A higher dry matter percentage may indicate a bigger concentration of phytochemical compounds; high values may also be associated with an advanced degree of drying or a higher content of fibrous components (Xiaoli et al. 2013). One of the current problems which involves tea bags is the large amount of food-derived waste produced annually. The utilized vegetable matter contributes to the increase in waste (Vern *et al.* 2023; Toplicean & Datcu, 2024), and techniques that include them in circular economy cycles are of interest. Among these, we can mention hydrothermal carbonization techniques, gasification, and pyrolysis (Duarah *et al.* 2022). Some research in this domain includes the successful utilization of waste as part of compost which promotes radish seedlings development (Tarashkar *et al.* 2023), but future studies on the utility of tea residues, including those from fruit and flowers should be considered.

CONCLUSIONS

To summarize, the gravimetric analysis of several fruit tea assortments showed significant variations in terms of IWQ (g), H (%), DM (%). Composition and processing methods strongly influence the physical parameters of teas; these differences being statistically supported by various tests. A high phytochemical density corresponds to a significant quantity of dry matter; this is a key indicator of technological and nutritional quality. The study highlights gravimetric analysis for assessing the quality and shelf life of herbal and fruit teas. Future investigations should include these main characteristics analyzed for used tea bags, but also other biochemical assessments to describe tea waste, as part of a circular bioeconomy cycle.

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