

QUANTITATIVE EVALUATION OF PHENOLICS, FLAVONOIDS AND CAFFEINE IN RELATION TO DPPH AND ABTS ANTIOXIDANT ACTIVITY OF ARIZONA® READY-TO-DRINK TEAS

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Abstract

This study presents a comparative evaluation of the phytochemical composition and *in vitro* antioxidant activity of eleven commercially available AriZona® ready-to-drink (RTD) tea variants. Total phenolic content (TPC), total flavonoid content (TFC), and caffeine concentration were quantified, and antioxidant capacity was assessed using DPPH and ABTS radical scavenging assays. Phenolic compounds were the dominant phytochemicals across all samples (182.7–319.5 mg GAE/g), followed by flavonoids (12.3–47.5 mg QE/g) and caffeine (30.6–96.2 mg/g), with substantial variability observed among flavors. Green Tea with Ginseng and Honey, Sweet Tea, and Blueberry White Tea exhibited the strongest antioxidant activity, while rooibos- and herbal-based formulations showed consistently lower performance. A strong negative correlation was observed between TPC and DPPH IC₅₀ values ($r = -0.77$), and a moderate correlation with ABTS IC₅₀ values ($r = -0.53$), confirming phenolic compounds as the primary contributors to antioxidant capacity, whereas flavonoids and caffeine showed weak or negligible associations. UV-Vis spectroscopy coupled with Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) effectively differentiated tea variants based on their chemical fingerprints, identifying rooibos- and cranberry-based teas as distinct outliers. Overall, the results demonstrate that RTD teas marketed under a single brand vary widely in phytochemical composition and functional properties, underscoring the importance of phytochemical profiling and multivariate analysis in evaluating antioxidant potential and informing consumer expectations.

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Introduction

Tea, derived from the leaves of *Camellia sinensis*, is the second most consumed beverage worldwide after water, largely due to its associated health benefits.¹ Epidemiological and clinical studies have shown that regular tea consumption may help reduce the risk of chronic diseases, including cardiovascular disease, neurodegenerative disorders, and certain cancers, effects that are primarily attributed to its high content of antioxidant polyphenols.¹⁻³ These bioactive compounds most notably catechins in green tea and theaflavins and thearubigins in black tea mitigate oxidative stress by donating hydrogen atoms or electrons from their phenolic hydroxyl groups to neutralize reactive oxygen species.⁴⁻⁶

Over the past several decades, the global market for ready-to-drink (RTD) teas has expanded rapidly, evolving into a multi-billion-dollar industry.⁷ Since their introduction in the 1980s, RTD teas have gained popularity as convenient alternatives to freshly brewed tea, particularly among younger consumers seeking functional beverages.⁸ Brands such as AriZona® have played a central role in this expansion by offering a wide variety of flavored tea-based beverages. Founded in 1992, AriZona® quickly became one of the most recognizable RTD tea brands in the United States. Although manufacturers often provide general information on ingredients and caffeine content, for example, approximately 15 mg of caffeine per 8 oz serving of black tea, independent, peer-reviewed data on the phytochemical composition and antioxidant properties of individual RTD tea products remain limited.^{9,10}

Unlike freshly brewed tea, RTD tea beverages undergo extensive processing and frequently contain added sugars, fruit juices, herbal extracts, flavorings, and preservatives.¹¹ These modifica-

tions can substantially alter the concentration, composition, and bioavailability of antioxidant compounds relative to traditionally brewed teas.¹²⁻¹³ Consequently, consumer perceptions of RTD teas as inherently “healthy” beverages may not always reflect their actual biochemical profiles. Despite their widespread consumption, systematic comparative studies evaluating antioxidant activity and phytochemical variability across different RTD tea flavors within the same commercial brand are scarce.

In addition to conventional antioxidant assays, spectroscopic and chemometric techniques have emerged as valuable tools for characterizing complex beverage matrices. UV-Visible (UV-Vis) spectroscopy, when coupled with multivariate statistical analyses such as Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA), enables rapid classification and differentiation of products based on their overall chemical fingerprints.¹⁴⁻¹⁶ These approaches have been successfully applied to authenticate teas, assess quality variation, and distinguish products based on botanical origin or formulation, yet their application to commercial RTD teas remains relatively unexplored.

To address these gaps, the present study systematically investigates eleven commercially available AriZona® RTD tea variants. The objectives of this work were to: (1) quantify total phenolic, flavonoid, and caffeine contents; (2) evaluate antioxidant capacity using DPPH and ABTS radical scavenging assays; (3) examine correlations between phytochemical composition and antioxidant activity; and (4) apply chemometric techniques (PCA and HCA) to classify tea samples based on their UV-Vis absorbance profiles. By integrating chemical analysis, antioxidant evaluation, and multivariate data analysis, this study provides a comprehensive assessment of the variability in functional properties among RTD

tea products and contributes to a more informed understanding of their potential health relevance.

Methodology

Sample Selection and Preparation.

Eleven commercially available AriZona® ready-to-drink (RTD) tea beverages were purchased from local retail stores in New York, NY, USA. The selected samples represented a range of tea bases and flavor profiles and were categorized as follows: black tea-based (Iced Tea with Cranberry, Iced Tea with Raspberry, Diet Peach Tea, Sweet Tea), green tea-based (Green Tea with Ginseng and Honey, Green Tea with Cucumber, Herbal Tonic), white tea-based (Blueberry White Tea), and rooibos-based (Red Tea). Lemon Tea and Half & Half (tea-lemonade blend) (Figure 1) were also included due to their popularity and compositional diversity.

Each beverage was transferred into sterile polypropylene vials immediately after opening and stored at 4°C until analysis. All samples were analyzed within one week of purchase. Unless otherwise specified, samples were analyzed without further dilution to reflect consumer-ready formulations.

Total Phenolic Content (TPC).

Total phenolic content was determined using the Folin–Ciocalteu colorimetric method, following established procedures with minor modifications.¹⁷ Briefly, 20 µL of tea sample or gallic acid standard solution (5–500 µg/mL) was mixed with 100 µL of Folin–Ciocalteu reagent in a 96-well microplate. After 4 min of reaction time, 100 µL of 1.0 M sodium carbonate solution was added to each well. The reaction mixtures were incubated in the dark at room temperature for 2 h, and absorbance was measured at 645 nm using a microplate reader.

A gallic acid calibration curve was constructed ($R^2 > 0.99$), and total phenolic content was expressed as milligrams of gallic acid equivalents per gram of sample (mg GAE/g) using the following equation:

$$\text{TPC (mg GAE/g)} = \frac{\text{Sample Absorbance} - 0.109}{0.0053}$$

Total Flavonoid Content (TFC).

Total flavonoid content was quantified using the aluminum chloride colorimetric method.¹⁸ Quercetin standard solutions (10–500 µg/mL) were used for calibration. In a 96-well plate, 20 µL of tea sample or quercetin standard was mixed with 200 µL of freshly prepared reagent consisting of aluminum chloride, ethanol, and sodium hydroxide in a 1:15:1 (v/v/v) ratio. The reaction mixtures were incubated in the dark for 30 min at room temperature, after which absorbance was measured at 420 nm.



Figure 1. AriZona tea samples used in this study.

Total flavonoid content was calculated from the quercetin calibration curve ($R^2 > 0.99$) and expressed as milligrams of quercetin equivalents per gram of sample (mg QE/g), using the equation:

$$\text{TFC (mg QE/g)} = \frac{\text{Sample Absorbance} + 0.0564}{0.0046}$$

Caffeine Content.

Caffeine content was estimated using UV-Visible spectrophotometry following the method used in an earlier study.¹⁹ A 0.10 mL aliquot of each tea sample was diluted to 10.0 mL with deionized water in a volumetric flask. UV-Vis absorbance spectra were recorded from 200 to 500 nm using a JASCO V-600 spectrophotometer.

Standard caffeine solutions (0.5–10 ppm) were prepared in deionized water, and a calibration curve was constructed using absorbance values at the characteristic caffeine absorbance maximum (267–279 nm). Caffeine concentrations were determined from the calibration curve and expressed in mg/g of sample.

DPPH Radical Scavenging Assay.

The DPPH radical scavenging assay was performed to evaluate antioxidant activity based on the reduction of the stable DPPH radical (1,1-diphenyl-2-picrylhydrazyl)²⁰ A 0.40 mM DPPH solution was prepared in methanol. Aliquots of AriZona tea samples (2–20 µL) were added in triplicate to a 96-well microplate, followed by 200 µL of DPPH solution. The plate was incubated in the dark at room temperature for 30 min, and absorbance was measured at 519 nm.

The percentage of radical scavenging activity was calculated relative to a control, and results were expressed as the half-maximal inhibitory concentration (IC_{50} , µg/mL), determined from dose-response curves.

ABTS Assay.

The ABTS⁺ radical cation assay was performed according to the method described by Re et al (1999).²¹ The ABTS⁺ radical was generated by reacting equal volumes of 7.4 mM ABTS stock solution and 2.6 mM potassium persulfate, followed by incubation in the dark at room temperature for 16 h. The resulting solution was diluted with ethanol to obtain an absorbance of 0.70 ± 0.02 at 745 nm.

AriZona samples (1–10 µL) were added in triplicate to a 96-well plate, followed by 200 µL of diluted ABTS⁺ solution. After incubation in the dark for 10 min, absorbance was measured at 745 nm. Antioxidant activity was expressed as IC_{50} values (µg/mL).

Statistical and Multivariate Analysis.

All experimental measurements were performed in triplicate, and results are reported as mean \pm standard deviation. Pearson correlation analysis was used to evaluate relationships between phytochemical content (TPC, TFC, caffeine) and antioxidant activity (IC_{50} values from DPPH and ABTS assays).

For multivariate analysis, UV-Vis absorbance spectra (200–500 nm) were exported from Excel into OriginPro (OriginLab Corp., Northampton, MA, USA). Principal Component Analysis (PCA) was conducted using mean-centered data without addition-

al scaling. Hierarchical Cluster Analysis (HCA) was performed using Euclidean distance and Ward's linkage method. PCA and HCA procedures followed previously reported methodologies for beverage classification.^{16, 19, 22}

Results and Discussion

Phenolic, Flavonoid, and Caffeine Content.

The total phenolic content (TPC), total flavonoid content (TFC), and caffeine concentration of the eleven AriZona® ready-to-drink (RTD) tea variants are presented in Figure 2. Across all samples, phenolic compounds were the most abundant phytochemical constituents, with concentrations ranging from 182.7 to 319.5 mg GAE/g. Blueberry White Tea, Cranberry Tea, Green Tea with Ginseng and Honey, and Half & Half exhibited the highest phenolic levels, each exceeding 300 mg GAE/g, whereas Red Tea (rooibos-based) and Herbal Tonic showed the lowest values.

The dominance of phenolic compounds observed in this study is consistent with numerous reports identifying polyphenols as the primary bioactive components of tea beverages.^{1,2} Phenolic compounds such as catechins, theaflavins, and phenolic acids contribute significantly to the antioxidant potential of both brewed and commercial tea products.^{3,4} The elevated phenolic content in Green Tea with Ginseng and Honey aligns with the known abundance of catechins in green tea, particularly epigallocatechin gallate (EGCG), while the high values observed for Blueberry White Tea and Cranberry Tea may reflect additional contributions from fruit-derived phenolics and anthocyanins.

Total flavonoid content was substantially lower than total phenolics for all samples, ranging from 12.3 to 47.5 mg QE/g. Cranberry Tea and Herbal Tonic exhibited comparatively higher flavonoid concentrations than other flavors. This trend is consistent with the inclusion of fruit extracts and herbal components, which are rich sources of flavonoids, particularly anthocyanins and flavonols.^{4,10} The relatively modest flavonoid levels across most samples further support the understanding that flavonoids represent only a subset of the broader phenolic pool quantified by the Folin-Ciocalteu assay.

Caffeine concentrations varied widely among the RTD teas, ranging from 30.6 to 96.2 mg/g. The highest caffeine levels were observed in Green Tea with Ginseng and Honey and Lemon Tea,

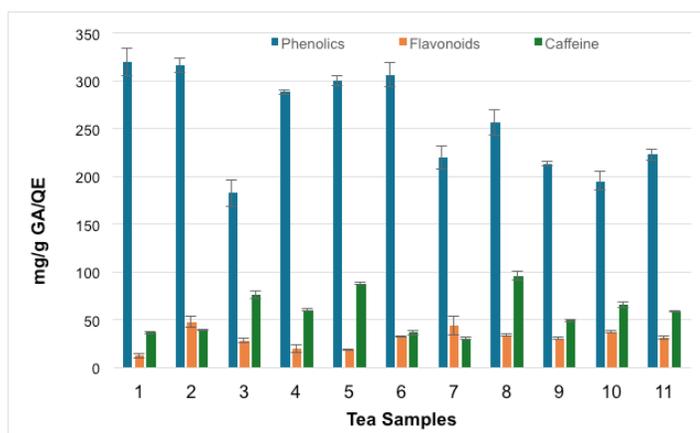


Figure 2. Comparison of total phenolic, flavonoid, and caffeine contents in AriZona® ready-to-drink teas.

while Red Tea exhibited the lowest apparent caffeine concentration. Variability in caffeine content among tea beverages has been attributed to differences in tea base, leaf processing, extraction efficiency, and formulation practices, including dilution and blending with non-tea ingredients.^{7,8} The low caffeine content observed for Red Tea is consistent with its rooibos base, as *Aspalathus linearis* is naturally caffeine-free.⁹

Notably, measurable absorbance in the caffeine-associated UV region was still detected for Red Tea, suggesting spectral interference from non-caffeine constituents (Figure 3). Rooibos contains unique dihydrochalcone glycosides, such as aspalathin, which absorb in similar ultraviolet regions and may contribute to overestimation when UV-Vis spectroscopy is used for caffeine determination in complex matrices.¹⁹ This highlights a methodological limitation of UV-Vis analysis for selective caffeine quantification and underscores the need for chromatographic confirmation in future studies.

Antioxidant Activity.

The antioxidant capacities of the eleven AriZona® ready-to-drink (RTD) tea variants were evaluated using DPPH and ABTS radical scavenging assays, and the results are expressed as IC₅₀ values in Table 1. Lower IC₅₀ values correspond to greater radical scavenging activity. Substantial variability in antioxidant activity was observed across the different tea formulations, reflecting differences in phytochemical composition and antioxidant quality. In the DPPH assay, Blueberry White Tea and Green Tea with Ginseng and Honey exhibited the strongest radical scavenging activity, with IC₅₀ values of 4.44 ± 0.01 µg/mL and 4.48 ± 0.62 µg/mL, respectively. These samples also ranked among those with the highest total phenolic content, supporting the established role of tea polyphenols as efficient hydrogen- and electron-donating antioxidants.^{3,20} In contrast, Red Tea and Herbal Tonic showed the weakest DPPH activity, consistent with their comparatively lower phenolic concentrations and, in the case of rooibos, the absence of catechin-type flavanols typical of *Camellia sinensis* teas.⁹

The ABTS assay revealed a different antioxidant activity profile. Sweet Tea and Green Tea with Ginseng and Honey demonstrated the highest ABTS radical scavenging capacity, with IC₅₀ values of 0.41 ± 0.15 µg/mL and 0.47 ± 0.04 µg/mL, respectively.

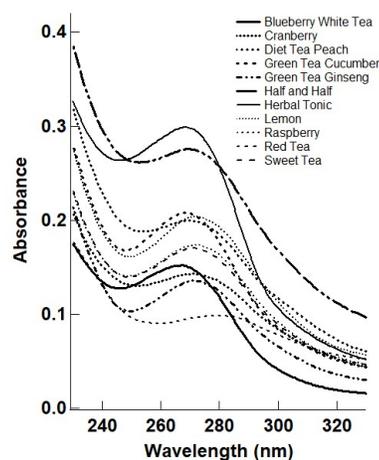


Figure 3. Absorbance of AriZona tea samples used in this study.

Raspberry Tea and Herbal Tonic exhibited the weakest activity in this assay. Across all samples, ABTS IC₅₀ values were generally an order of magnitude lower than those obtained from the DPPH assay, a trend that has been widely reported and attributed to the broader reactivity of the ABTS radical cation toward both hydrophilic and lipophilic antioxidants.^{10,21}

The divergence in sample rankings between the two assays highlights important differences in antioxidant mechanisms captured by DPPH and ABTS methods. The DPPH assay primarily reflects the ability of compounds to donate hydrogen atoms to a stable nitrogen-centered radical, favoring lipophilic antioxidants. In contrast, the ABTS assay is sensitive to a wider spectrum of antioxidant species, including phenolic acids, flavonoids, and anthocyanins.²¹ This broader sensitivity likely explains the exceptionally strong ABTS activity observed for Sweet Tea, despite its only moderate total phenolic content. Such behavior suggests that the qualitative composition of antioxidants rather than total concentration alone plays a critical role in ABTS scavenging efficiency.

Fruit-flavored teas, particularly Cranberry Tea and Raspberry Tea, exhibited stronger ABTS activity relative to their DPPH performance. This trend is consistent with the known reactivity of anthocyanins and other fruit-derived polyphenols toward the ABTS radical, as previously reported for berry-based beverages.¹⁰ Conversely, rooibos-based Red Tea consistently showed weaker antioxidant activity in both assays, reflecting its distinct polyphenolic profile dominated by dihydrochalcone glycosides, which are generally less potent radical scavengers than catechins and anthocyanins.⁹

Correlation Analysis.

To further elucidate the relationships between chemical composition and antioxidant performance, correlation analysis was conducted between total phenolic content (TPC), total flavonoid content (TFC), caffeine concentration, and antioxidant activity as measured by DPPH and ABTS IC₅₀ values (Table 2). This analysis provides quantitative insight into which phytochemical classes most strongly influence radical scavenging behavior in AriZona® RTD teas.

A strong negative correlation was observed between TPC and DPPH IC₅₀ values ($r = -0.77$, $p < 0.01$), indicating that samples with higher phenolic content consistently exhibited stronger DPPH radical scavenging activity. A moderate negative correlation was

also observed between TPC and ABTS IC₅₀ values ($r = -0.53$, $p < 0.05$). These findings are consistent with previous studies on tea infusions and plant-based beverages, which have repeatedly demonstrated phenolic compounds as the primary contributors to antioxidant capacity measured by chemical radical scavenging assays.¹⁰⁻¹²

In contrast, total flavonoid content showed weak and non-significant correlations with both DPPH ($r = +0.40$) and ABTS ($r = +0.26$) IC₅₀ values. Although flavonoids are recognized antioxidants, this result likely reflects the methodological specificity of the aluminum chloride assay, which selectively detects certain flavonoid subclasses and may not accurately represent the full spectrum of flavonoid antioxidants present in complex tea formulations.¹⁸ Furthermore, flavonoids constitute only a portion of the total phenolic pool quantified by the Folin-Ciocalteu method, which also captures phenolic acids and other reducing compounds with strong antioxidant activity.

Caffeine content exhibited no meaningful correlation with DPPH IC₅₀ values and only a weak, non-significant negative correlation with ABTS IC₅₀ values. This observation reinforces the established understanding that caffeine contributes minimally to antioxidant activity in tea beverages compared to polyphenolic constituents.¹³ While caffeine is a major bioactive compound affecting stimulant properties and sensory perception, its role in radical scavenging appears negligible in the context of RTD tea formulations.

Collectively, the correlation analysis confirms that total phenolic content is the most reliable predictor of antioxidant capacity among the measured variables. However, the weaker correlations observed for ABTS activity further suggest that antioxidant effectiveness is influenced not only by the quantity of phenolics but also by their qualitative composition and potential synergistic interactions among different antioxidant species.

UV-Vis Spectroscopy and Chemometric Classification.

UV-Visible (UV-Vis) spectroscopy coupled with multivariate chemometric analysis was employed to evaluate similarities and differences in the overall chemical profiles of the AriZona® ready-to-drink (RTD) teas. Principal Component Analysis (PCA) was applied to the full UV-Vis absorbance spectra (200–500 nm) to reduce data dimensionality and visualize sample clustering based on spectral fingerprints.

The PCA score plot (Figure 4) shows that the first two principal components accounted for 96.7% of the total variance, with PC1 explaining 89.9% and PC2 accounting for 6.8%. Red Tea and Cranberry Tea were positioned far from the origin along PC1, indicating chemical compositions that are distinct from the remain-

Table 1. IC₅₀ values of the eleven AriZona samples based on DPPH and ABTS assay indicating antioxidant activity.

Tea Samples	IC ₅₀ (ug/mL) DPPH	IC ₅₀ (ug/mL) ABTS
1. blueberry white tea	4.44 ± 0.01	3.73 ± 0.02
2. cranberry	4.86 ± 0.11	2.54 ± 0.04
3. diet tea peach	8.70 ± 0.18	4.87 ± 0.01
4. green tea cucumber	4.89 ± 0.12	2.34 ± 0.11
5. green tea ginseng	4.48 ± 0.62	0.47 ± 0.04
6. half & half	5.10 ± 0.01	2.33 ± 0.22
7. herbal tonic	8.75 ± 9.25	5.73 ± 0.19
8. lemon	4.84 ± 0.40	2.29 ± 0.01
9. raspberry	5.72 ± 0.03	5.47 ± 0.28
10. red tea	11.58 ± 0.09	4.60 ± 0.02
11. sweet tea	5.50 ± 0.01	0.41 ± 0.15

Table 2. Correlation analysis between phytochemical content and antioxidant capacity of AriZona® RTD teas.

	Phenolics	Flavonoids	Caffeine	DPPH	ABTS
Phenolics	1				
Flavonoids	-0.30	1			
Caffeine	-0.22	-0.24	1		
DPPH	-0.77	0.40	-0.004	1	
ABTS	-0.53	0.26	-0.36	0.62	1

ing tea samples. This separation reflects the unique phytochemical characteristics of these beverages. Rooibos-based Red Tea lacks the catechin-rich profile typical of *Camellia sinensis* teas and instead contains characteristic dihydrochalcone glycosides, while Cranberry Tea is enriched with fruit-derived phenolics, including anthocyanins, which contribute to distinct spectral behavior.^{9,10} The clustering observed in the PCA score plot indicates that many of the green and black tea-based beverages share similar UV-Vis spectral features, suggesting comparable underlying chemical compositions despite differences in branding and flavoring. This result demonstrates that UV-Vis spectroscopy alone, when combined with multivariate analysis, is sufficient to capture meaningful compositional variation among complex commercial beverage formulations.

Hierarchical Cluster Analysis (HCA) was performed to complement the PCA and further evaluate sample similarity based on Euclidean distance and Ward's linkage method. The resulting dendrogram (Figure 5) revealed two primary clusters. Cluster I consisted exclusively of Red Tea, confirming its distinct chemical fingerprint. Cluster II contained the remaining ten samples and was further subdivided, with Cranberry Tea forming a distinct subclus-

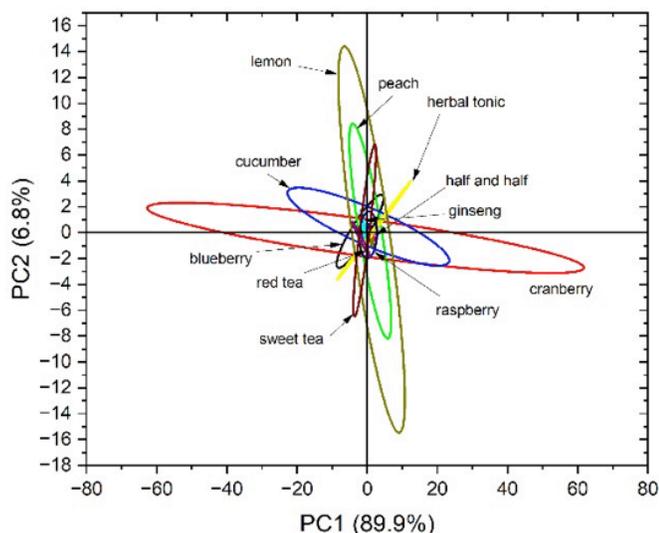


Figure 4. PCA of absorbance of AriZona tea samples used in this study.

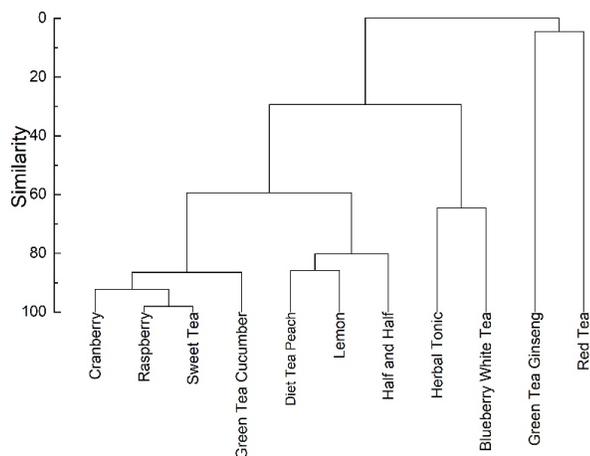


Figure 5. HCA of average absorbance of AriZona tea samples used in this study.

ter separate from the other RTD teas. Within the larger subgroup, Lemon Tea, Half & Half, Green Tea with Ginseng and Honey, and Green Tea with Cucumber exhibited the highest degree of similarity, indicating closely related spectral profiles.

The combined PCA score plot and HCA dendrogram demonstrate the effectiveness of UV-Vis-based chemometric approaches for the rapid classification and comparison of commercial RTD teas. Similar strategies have been successfully applied for tea authentication, quality control, and differentiation based on botanical origin and formulation.¹⁴ In the context of this study, chemometric analysis provides complementary evidence supporting the observed variability in phytochemical composition and antioxidant activity among AriZona® RTD tea variants, while remaining consistent with the experimental data obtained.

It is important to note that UV-Vis spectroscopy is a relatively non-specific analytical technique, particularly when applied to complex consumer beverages such as ready-to-drink teas, where multiple constituents may exhibit overlapping absorption profiles. However, the successful differentiation of tea variants observed in this study demonstrates that coupling UV-Vis spectral data with multivariate chemometric techniques such as PCA and HCA can effectively resolve overlapping signals and extract meaningful compositional information. This combined approach enhances the interpretive power of UV-Vis spectroscopy and supports its application as a rapid screening and classification tool for complex beverage matrices.

Conclusion

This study presents a systematic comparative analysis of the phytochemical composition and *in vitro* antioxidant activity of eleven commercially available AriZona® ready-to-drink (RTD) teas. The results demonstrate substantial variability among flavors within a single brand, driven primarily by differences in total phenolic content and formulation. Phenolic compounds emerged as the dominant contributors to antioxidant capacity, showing strong correlations with DPPH and moderate correlations with ABTS radical scavenging activity, whereas flavonoids and caffeine played comparatively minor roles.

The combined use of DPPH and ABTS assays revealed that antioxidant effectiveness depends not only on total phenolic concentration but also on the qualitative profile of antioxidants present. Formulations containing green tea bases and fruit or botanical additives such as Green Tea with Ginseng and Honey, Sweet Tea, and Blueberry White Tea exhibited the strongest antioxidant activity, while rooibos-based and herbal formulations showed consistently lower performance. These findings highlight the importance of employing multiple antioxidant assays to capture the complexity of antioxidant behavior in commercial beverage systems.

Chemometric analysis using UV-Vis spectroscopy, Principal Component Analysis (PCA), and Hierarchical Cluster Analysis (HCA) successfully differentiated tea variants based on their overall chemical fingerprints. The distinct clustering of rooibos- and cranberry-based teas underscores the influence of botanical origin and formulation on spectral and functional properties. Importantly, caffeine content was shown to be a poor predictor of antioxidant

potential, a distinction relevant to both consumers and product developers.

Overall, this work demonstrates that RTD teas marketed under a common brand do not provide uniform functional benefits. From an analytical perspective, the study highlights the value of combining straightforward spectroscopic techniques with multivariate analysis to characterize complex commercial products. Future studies employing chromatographic methods to identify individual phenolic compounds and in vivo or cellular antioxidant models would provide deeper insight into the biological relevance of these findings. Collectively, this study contributes to a more informed understanding of the chemical and functional diversity of RTD teas and reinforces the importance of phytochemical profiling in evaluating their potential health significance.

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References

- Cabrera, C., Artacho, R., & Giménez, R. (2006). *Journal of the American College of Nutrition*, 25(2), 79–99. <https://doi.org/10.1080/07315724.2006.10719518>
- Frei, B., & Higdon, J. V. (2003). *The Journal of Nutrition*, 133(10), 3275S–3284S. <https://doi.org/10.1093/jn/133.10.3275S>
- Carlioni, P., Tiano, L., Padella, L., Bacchetti, T., Customu, C., Kay, A., & Damiani, E. (2013). *Food Research International*, 53(2), 900–908. <https://doi.org/10.1016/j.foodres.2012.07.057>
- Rice-Evans, C. A., Miller, N. J., & Paganga, G. (1996). *Free Radical Biology and Medicine*, 20(7), 933–956. [https://doi.org/10.1016/0891-5849\(95\)02227-9](https://doi.org/10.1016/0891-5849(95)02227-9)
- Prior, R. L., Cao, G., Martin, A., Sofic, E., McEwen, J., O'Brien, C., Mainland, C. M., & Gu, L. (1998). *Journal of Agricultural and Food Chemistry*, 46(7), 2686–2693. <https://doi.org/10.1021/jf980145d>
- Rusak, G., Komes, D., Likić, S., Horžić, D., & Kovač, M. (2008). *Food Chemistry*, 110(4), 852–858. <https://doi.org/10.1016/j.foodchem.2008.02.072>
- Lin, Y. S., Tsai, Y. J., Tsay, J. S., & Lin, J. K. (2003). *Journal of Agricultural and Food Chemistry*, 51(7), 1864–1873. <https://doi.org/10.1021/jf021066b>
- Wang, H., Helliwell, K., & You, X. (2011). *Food Chemistry*, 68(1), 115–121. [https://doi.org/10.1016/S0308-8146\(99\)00179-X](https://doi.org/10.1016/S0308-8146(99)00179-X)
- Joubert, E., & de Beer, D. (2011). *South African Journal of Botany*, 77(4), 869–886. <https://doi.org/10.1016/j.sajb.2011.07.004>
- Prior, R. L., Wu, X., & Schaich, K. (2005). *Journal of Agricultural and Food Chemistry*, 53(10), 4290–4302. <https://doi.org/10.1021/jf0502698>
- Pérez-Jiménez, J., Arranz, S., Taberner, M., Díaz-Rubio, M. E., Serrano, J., Goñi, I., & Saura-Calixto, F. (2010). *Food Research International*, 41(3), 274–285. <https://doi.org/10.1016/j.foodres.2007.12.004>
- Zhao, C. N., Tang, G. Y., Cao, S. Y., Xu, X. Y., Gan, R. Y., Liu, Q., Mao, Q. Q., Shang, A., & Li, H. B. (2019). Phenolic profiles and antioxidant activities of 30 tea infusions from green, black, oolong, white, yellow, and dark teas. *Antioxidants*, 8(7), 215. <https://doi.org/10.3390/antiox8070215>
- Azam, S., Hadi, N., Khan, N. U., & Hadi, S. M. (2004). *Medical Science Monitor*, 10(9), BR325–BR330.
- Aboulwafa, M. M., Youssef, F. S., Gad, H. A., Sarker, S. D., Nahar, L., Al-Azizi, M. M., & Ashour, M. L. (2019). *Journal of Pharmaceutical and Biomedical Analysis*, 164, 653–658. <https://doi.org/10.1016/j.jpba.2018.11.036>
- Vuletic, N. & Bardic, L. & Odžak, Renata. (2021). *Food Research*. 5. 325-330.
- Murtagh, F., & Legendre, P. (2014). *Journal of Classification*, 31(3), 274–295. <https://doi.org/10.1007/s00357-014-9161-z>
- Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). *Methods in Enzymology*, 299, 152–178. [https://doi.org/10.1016/S0076-6879\(99\)99017-1](https://doi.org/10.1016/S0076-6879(99)99017-1)
- Zhishen, J., Mengcheng, T., & Jianming, W. (1999). *Food Chemistry*, 64(4), 555–559. [https://doi.org/10.1016/S0308-8146\(98\)00102-2](https://doi.org/10.1016/S0308-8146(98)00102-2)
- Duval, T., Sullivan, C., Romanova, A., & Mojica, E.-R. E. (2025). *Journal of Undergraduate Chemistry Research*, 24(4), 110–115.
- Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). *LWT – Food Science and Technology*, 28(1), 25–30. [https://doi.org/10.1016/S0023-6438\(95\)80008-5](https://doi.org/10.1016/S0023-6438(95)80008-5)
- Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1999). *Free Radical Biology and Medicine*, 26(9–10), 1231–1237. [https://doi.org/10.1016/S0891-5849\(98\)00315-3](https://doi.org/10.1016/S0891-5849(98)00315-3)
- Jolliffe, I. T., & Cadima, J. (2016). *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374(2065), 20150202. <https://doi.org/10.1098/rsta.2015.0202>