Heliyon 9 (2023) e12638

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Quality characteristics of green Tea's infusion as influenced by brands and types of brewing water

Hui-Ling Tan [a], Moses Ojukwu [b], Le-Xuan Lee [b], Azhar Mat Easa [b,*]

[a] School of Hospitality and Service Management, Sunway Universiti, 47500, Petaling Jaya, Selangor, Malaysia
[b] Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, 11800 USM, Penang, Malaysia

ARTICLE INFO

Keywords:
Antioxidant capacity
Physicochemical properties
Green tea
Brewing water

ABSTRACT

The influences of four types of brewing waters including tap water (TAP), alkaline ionized water (ALK), magnetized water (MAG) and mineral water (MIN), and two brands of commercial green tea (L and T) on quality characteristics of tea infusions were studied.

The Oxidation Reduction Potential (ORP) values of the brewing waters was TAP > MAG, MIN > ALK. After brewing, all infusions showed a significant drop ($p < 0.05$) in pH values. The pH of original brewing waters of ALK (8.64) was the highest as compared to other waters, whereas L-MIN (pH 6.63) and T-MIN (pH 5.82) showed the highest pH values after brewing. Overall, the quality characteristics of green tea infusions were influenced by the brands of tea and the types of brewing water used. MAG was the most superior brewing water in extracting the green tea. Evidenced by total phenolic and flavonoids contents, both L-MAG and T-MAG infusions were superior in extracting antioxidative compounds as compared to other tea infusions. In addition, T-MAG infusion was the least astringent ($P < 0.05$) and scored the highest ($P < 0.05$) overall acceptability (5.40) by sensory panelists.

1. Introduction

Green tea has shown its potential health benefits by having high content of catechins and polyphenols which are important components in tea leaves [1]. The health advantages of drinking water have been revealed tremendously by manufacturers. Treatment with some minerals, irradiation, magnetization, and others are utilized to produce drinking water with health benefits. Since green tea is a beverage that can bring health benefits to the consumers, it is expected that its effect maybe optimized by brewing it with a strategic drinking water.

There are numerous research have been conducted to explore impacts of water quality on green tea infusion [2]. In addition, there are various aspects of the brewing condition of green tea have been explored such as brewing time, temperature and pH of brewing water, and so on. But little is explored on the impacts of types of drinking water used and water quality on the properties of the green tea [3].

According to Ref. [4]; water hardness, ion content, and pH determine quality of brewing water [5]. reported that interaction between catechins and water components and caused the flavour profile of the infusions to be affected by the water composition. The use of tap water for tea preparation is the most common method used by casual tea consumers [6]. However, the sensory preferences for tap water infused tea were inconsistent which might be due to the variation of water composition of tap water in different regions.

* Corresponding author.
E-mail address: azhar@usm.my (A. Mat Easa).

https://doi.org/10.1016/j.heliyon.2022.e12638
Received 12 July 2022; Received in revised form 23 November 2022; Accepted 20 December 2022
Available online 26 December 2022

One of the major developments in water technology is the development of alkaline water owing to its alleged health benefits. It is a popular drinking water which is also known as alkaline electrolyzed water [7]. It has been established that this water is suitable for human consumption as it is commonly used as a treatment for gastro-intestinal disorders [8]. Another interesting development is the surge of interest in magnetized water. Previous studies showed that when the water was treated under a magnetic field, the pH of water increased depending on the intensity of the magnetic field [9]. Absorption of hydrogen ions cause the concentration of hydroxyl ions to increase, form alkaline molecules which create an alkaline environment [7]. Despite of the cost there were several researches that adopted the method of steeping green tea in mineral water [10]. It was suggested that using mineral water to brew green tea infusion could significantly influence the quality attributes of the brew. Mineral salts can exert a variety of effects on extraction mechanism of green tea infusion [6].

Various research have proven that tea catechins help to reduce the risk of heart diseases [11]. Based on the previous studies, different water treatments led to changes in composition of brewing water which directly affected the final qualities attributes of tea brews. This was done via proactive interactions of catechins in tea with components of water. To date, there is a lacking information on the effects of using brewing water such as magnetized or alkaline water on the qualities of green tea. The extraction of green tea by brewing waters might different and hence would yield different impacts on qualities of the tea infusions.

Moreover, different brands of green tea were also one of the important factors. Therefore, two brands that were selected for the study: premium Brand T and standard brand L. The objective was to investigate effects of types and composition brewing water on the physicochemical properties, antioxidant activity, and sensory acceptability of premium and standard green tea infusion. The findings obtained from this study would reveal the impact of brewing water on the qualities of tea infusions, which contributed information and guidance about the selection of suitable brewing water used for green tea.

2. Materials and methods

2.1. Materials

Brand T green tea which manufactured by TWG Tea Company Pte Ltd. was purchased from Gurney Paragon (Penang, Malaysia). Each box contains 15 infusion bags with each approximately 2.5 g. Composition of brand T green tea is a green tea blend with red fruits and caramel. Brand L green tea which contains 50 Teabags x 2 g (100 g) are manufactured by Unilever (Malaysia) Holdings Sdn. Bhd. It was purchased from the online shopping site Shopee. The compositon of brand L green tea include water, high fructose corn syrup, citric acid, natural flavor, sodium hexametaphosphate, green tea, ascorbic acid (vitamin C), potassium sorbate, phosphoric acid, sugar, acesulfame potassium, calcium disodium EDTA, and honey.

Tap water (TAP) was collected from domestic tap in the research lab 225, School of Industrial Technology, Universiti Sains Malaysia. The HOH® magnetized water (MAG) was purchased from Bio Eng Creations (M) Sdn Bhd (Penang, Malaysia). The EOSG 7+ alkaline water (ALK) was produced by EOSG International Sdn Bhd whereas Spritzer mineral water (MIN) was manufactured by Spritzer Bhd. Both ALK and MIN were also purchased from online shopping site Shopee.

All reagents and chemicals used in this study were of analytical grade. Concentrated nitric acid, hydrochloric acid 37%, sodium hydroxide, ethanol 96%, and methanol were purchased from Qrec (Selangor, Malaysia). The 2,4,6-Tris (1-pyridyl)-5-triazine (TPTZ), 2,2-Diphenyl-1-picrylhydrazyl (DPPH), gallic acid, quercetin, and Whatman filter paper grade 42 were purchased from Sigma-Aldrich (Steinheim, Germany). Folin-Ciocalteu's phenol reagent and aluminium chloride hexahydrate ($AlCl_3.6H_2O$) were obtained from R&M Chemicals (Essex, UK). Sodium carbonate and sodium nitrite were purchased from Systerm Chemicals (Selangor, Malaysia). Lanthanum (III) oxide was purchased from Fisher Scientific (M) Sdn Bhd (Selangor, Malaysia). Calcium and sodium standard solution were obtained from Supelco, Inc (Pennsylvania, United States).

2.2. Preparation of green tea infusion

Tea infusions was prepared based on the conventional method. A bagged green tea was transferred to a beaker in which it was steeped in water (weight of tea leaves/water ratio of 1:5 (w/w)), at 80 ± 5 °C. The bagged green tea was brewed for 3 min. The tea bag was removed from the beaker after the brewing process. All the samples were cooled to room temperature. Subsequently, the analyses were performed in triplicate.

2.3. Physicochemical analysis of tea infusions

2.3.1. pH measurement

The pH measurements of tea samples were taken by following the methods from Ref. [12] by using a Seveneasy pH meter (Mettler-Toledo, Switzerland). Fresh standard buffer solutions of pH 4.0, 7.0, and 9.21 were used to calibrate pH meter before it was used at room temperature. The pH readings were made by triplicates and the findings were recorded as average.

2.3.2. Oxidation reduction potential (ORP)

The redox potential of the brewing water was determined according to the method described by Ref. [13]. The measurement was conducted with a multiparameter benchtop water quality meter (AZ, 86505 model, Taiwan). Three measurements were made and the findings were recorded as mV of infusions.

2.3.3. Colour

The colour measurements of green tea infusion were carried out within 5 h after brewing as described by Ref. [14]. The values of L* (lightness), a* (greenness and redness), b* (blueness and yellowness) were determined by using a colour spectrophotometer (Konica Minolta, CM-A128 Petri dish, Japan). Measurements were made by triplicates with each tea infusion sample was placed on the aperture.

2.3.4. Total soluble solids

The total soluble solids of samples were determined by using digital refractometer (Mettler Toledo, US) at ambient temperature according to the method described by Ref. [15]. A zero calibration for the measurement was done with distilled water. Several drops of the tea sample were added on the prism until it spread evenly on the surface of the prism without any gas bubbles. The sample reading was taken after 30 s under a light source. The instrument was rinsed with distilled water after each measurement. All the results were expressed as brix concentration (°Brix). Three readings were taken, and the findings were recorded as average.

2.3.5. Determination of mineral

Determination of mineral was conducted by following [16] with modifications. The measurements were performed by using Atomic Absorption Instrument (AAS) (PerkinElmer, Waltham, Massachusetts, USA). The digestion was performed using a microwave digestor (Milestone Ethos 900 microwave lab station, Sorisole, Italy). Prior to digestion process, the tea samples were filtered through filter paper (Whatman no. 42). Next, 5.0 mL of the supernatant was transferred into a polytetrafluoroethylene (PTFE) vessel. Then, 3.0 mL of concentrated nitric acid (HNO_3) was added into each vessel. The digestion process was allowed to run for 20 min after all the vessels were placed on the rotating turntable. The digested samples were then diluted to 25.0 mL with distilled water.

A series of calcium stock solution of 0, 0.5, 1, and 2 ppm were prepared from 1000 ppm calcium standard solution in 100 mL volumetric flask. Then, 20 mL of lanthanum (III) oxide (La_2O_3) solution was added followed by dilution to 100 mL with 1% HNO_3. For sodium content determination, a series of sodium standard solutions of 0, 0.05, 0.1, 0.2, and 0.5 ppm were prepared from 1000 ppm standard stock solution in 100 mL volumetric flask. The standard curves were plotted based on these standard solutions.

The measurements of calcium and sodium content were taken by water, reagent blank (0 ppm), sample blank, and test solutions accordingly. The measurements were examined by AAS with flame atomization operating. The determination of calcium and sodium contents was made in triplicates and the results were expressed as mg/L.

2.3.6. Antioxidant properties

2.3.6.1. Total phenolic content (TPC). The total phenolic content of the tea infusion was determined according to the method modified from Ref. [17]. Firstly, tea infusion was mixed with a solution of 5 mL of 3% HCl in methanol/deionized water (60:40, v/v) and the resulting mixture (100 mL) was added to 2 mL of 2% aqueous sodium carbonate solution. After 2 min, 100 mL of 50% Folin-Ciocalteu's reagent (Sigma-Aldrich) were added to the mixture in a test tube and left at room temperature. The test tube was vortexed and covered with parafilm. The mixture was then incubated and allowed to react in a dark room for 2 h at room temperature. A blank solution was prepared by adding 70% ethanol. The absorbance of all samples was measured at 750 nm against a blank using a mini spectrophotometer (Shimadzu, UV-VIS 1800, Japan). Gallic acid was used as standard for the calibration curve by plotting at standard working gallic acid solutions of 0.05, 0.10, 0.15, 0.20, and 0.25 mg/L. These solutions were prepared in 70% (v/v) ethanol by using a similar procedure. Measurements of TPC were made and calculated by triplicates. The results were then expressed as milligram of gallic acid equivalent (GAE) per mL of infusion, using the following standard curve equation (1):

$$y = 0.0165x - 0.0041, R^2 = 0.98751 \tag{1}$$

where y is the absorbance and x is the concentration of gallic acid in mg/L.

2.3.6.2. Flavonoid content. The flavonoid content (FC) was examined based on the colourimetric method described by and Jia et al. (1999) and Singla et al. (2009) with some modifications. Firstly, 1 mL of tea sample was transferred into a test tube which was wrapped with aluminium foil filled with 5 mL of distilled water and mixed with 0.6 mL of 5% sodium nitrite ($NaNO_2$) solution. Then, 0.6 mL of 10% aluminium chloride hexahydrate ($AlCl_3.6H_2O$) was added after 5 min. Next, 2 mL of 1 M sodium hydroxide (NaOH) and distilled water were added to mix up to a total volume of 10 mL. The solution in the test tube was vortexed by using a vortex mixer (Stuart, Staffordshire, UK). Meanwhile, a blank solution was prepared by adding 1 mL of extraction solvent and all other reagents. The absorbance readings of the samples were taken using 510 nm by using a Mini Spectrophotometer (Shimadzu, UV-VIS 1800, Japan) against the blank solution.

The calibration curve was plotted at the standard working quercetin solutions of 50, 100, 150, 200, and 250 mg/mL. These solutions were prepared in 80% (v/v) methanol using a similar procedure. The absorbance was measured by using 80% (v/v) methanol as a blank solution at 510 nm. Measurements and calculations of flavonoid content were made by triplicates. The results were then expressed as milligram of quercetin equivalent (QE) per 100 mL of green tea samples using the following standard curve equation (2):

$$y = 0.7988x + 0.0024, R^2 = 0.9998 \tag{2}$$

where y is the absorbance, x is the concentration of quercetin in mg/100 mL of infusion.

Table 1
pH of the brewing water and tea infusions brewed with different brewing water and brands of green tea, respectively.

Brand of green tea	Type of brewing water	Original pH of water	pH of tea infusion
L	TAP	$6.490.04^{aB}$	$5.410.08^{bC}$
	ALK	$8.640.19^{aA}$	$5.580.03^{bB}$
	MAG	$6.530.17^{aB}$	$5.580.07^{bB}$
	MIN	$6.630.04^{aB}$	$6.100.03^{bA}$
T	TAP	$6.490.04^{aB}$	$5.030.01^{bB}$
	ALK	$8.640.19^{aA}$	$5.100.01^{bB}$
	MAG	$6.530.17^{aB}$	$5.140.01^{bB}$
	MIN	$6.630.04^{aB}$	$5.820.04^{bA}$

* TAP = Tap water; ALK = Alkaline ionized water; MAG = Magnetized water; MIN = Mineral water.
* Each value is expressed as mean value ± standard deviation (n = 3).
* a-b, within the same row, with different superscript letters are significantly different at $p < 0.05$ by Tukey's HSD.
* A-C, within the same column for each brand of tea, with different superscript letter cases, are significantly different at $p < 0.05$ by Tukey's HSD.

2.3.6.3. Determination of 2,2-diphenyl-1-picrylhydrazyl free radical scavenging activity (DPPH-SA). The measurement of antioxidant capacity by following [18]. Radical scavenging activity of tea samples were examined spectrophotometrically. Firstly, 0.12 mL of tea samples or standard was added to 4 mL of 0.8 mg/mL DPPH in methanol. The mixture was mixed well and kept in the dark for 30 min at room temperature. The absorbance of the reaction mixture was taken at 517 nm with solvent as blank by using a mini spectrophotometer (Shimadzu, UV-VIS 1800, Japan). The absorbance of a blank sample with equal amount of methanol and DPPH solution was prepared and measured as control. All samples were measured and calculated in three replicates. The total antioxidant capacity was calculated based on the following equation (3) and expressed as %:

$$\text{Scavenging activity } (\%) = \left(1 - \frac{A}{B}\right) \times 100 \tag{3}$$

where A is absorbance of sample at 517 nm, B is absorbance of control at 517 nm.

2.4. Hedonic test

Hedonic test was performed after obtaining the ethical approval (USM/JEPeM/21100668). Appearance (colour), aroma, flavour, aftertaste, astringency, bitterness, and sensory acceptability of tea infusions were evaluated. The test was conducted using the 7-points hedonic scale and any parameter with scores more than 5 is acceptable. Samples (30 mL) were served to each panellist in a clean white teacup labelled with 3-digit codes and presented in a randomised order [19,20]. Tea samples were freshly brewed every 30 min at 80 °C [5]. All tea infusions were kept warm in insulated carafes before serving. There were total 30 untrained panellists from the School of Industrial Technology, Universiti Sains Malaysia, Penang, who consume green teas regularly, rated the tea infusions based on a 7-point hedonic scale (1 = dislike very much, 4 = neither like nor dislike, 7 = like very much). Informed consents were obtained from all participants who involved in the hedonic test. They were male and female students at the age range of 20–40 years old. Water was served to cleanse palette whereas non-salted crackers to avoid fatigue between samples.

2.5. Statistical analysis

Results were expressed as mean ± standard deviation. The results were statistically analyzed using SPSS software version 27.0 ($p < 0.05$) (SPSS Inc., Chicago, IL, USA). All the readings were taken by triplicates and comparison of means was performed by two-ways analysis of variance (ANOVA). When significance level was reached, independent T-test and a post-hoc Tukey HSD test were conducted.

3. Results and discussion

3.1. Physicochemical properties of tea infusions

3.1.1. pH analysis

Table 1 summarizes the pH values of the brewing water and tea infusions made using brand L and T green tea. ALK had the significantly highest ($p < 0.05$) original pH value than other brewing waters that was likely to be due to its basic nature in which ALK was produced using a process that promoted alkalinity of water.

All infusions showed a significant drop ($p < 0.05$) in pH values. These results were coincided with the results obtained by Ref. [21] in which pH of tea infusions decreased significantly ($p < 0.05$) after brewing with hard alkaline water. This indicated that the brewing process had an effect of lowering the pH value of tea infusion [6]; Xu et al., 2017) that might be due to the extraction of compounds in the tea leaves such as organic acids, phenols, carboxylic groups, and amino acids. The extraction process was mainly determined by the degree of fermentation of green tea ([46]; [22].

Table 2
Redox potential of different brewing water that expressed in mV of infusions, respectively.

Type of brewing water	ORP of brewing water
TAP	193.671.53^{A}
ALK	94.002.00^{C}
MAG	179.671.53^{B}
MIN	183.671.53^{B}

* TAP = Tap water; ALK = Alkaline ionized water; MAG = Magnetized water; MIN = Mineral water.
* Each value is expressed as mean value ± standard deviation (n = 3).
* A-B, within the same column, with different superscript letter cases, are significantly different at $p < 0.05$ by Tukey's HSD.

Table 3
L*, a*, b*, and h° value of tea infusions brewed with different brewing water and brands of green tea, respectively.

Analyses	Type of brewing water	Brand of green tea	
		L	T
L*	TAP	93.020.03^{aA}	93.520.18^{aB}
	ALK	92.330.28^{aBC}	90.830.06^{bC}
	MAG	92.520.16^{bB}	94.520.23^{aA}
	MIN	84.340.04^{bC}	89.820.29^{aD}
a*	TAP	−5.070.02^{bC}	−4.480.06^{aA}
	ALK	−5.760.07^{bD}	−4.740.03^{aB}
	MAG	−5.320.40^{bB}	−5.020.06^{aC}
	MIN	−3.630.02^{aA}	−7.500.10^{bD}
b*	TAP	35.110.04^{aC}	24.780.06^{bC}
	ALK	34.540.08^{aD}	32.420.07^{bB}
	MAG	37.950.05^{aB}	24.610.08^{bC}
	MIN	54.410.04^{aA}	49.420.07^{bA}
h°	TAP	98.220.02^{bB}	100.240.01^{aB}
	ALK	99.460.13^{aA}	98.300.06^{bC}
	MAG	98.030.02^{bB}	101.530.17^{aA}
	MIN	93.810.02^{bC}	98.630.12^{aC}

* TAP = Tap water; ALK = Alkaline ionized water; MAG = Magnetized water; MIN = Mineral water.
* Each value is expressed as mean value ± standard deviation (n = 3).
* a-b, within the same row, with different superscript letters are significantly different at $p < 0.05$ by Tukey's HSD.
* A-D, within the same column, with different superscript letter cases are significantly different at $p < 0.05$ by Tukey's HSD.
Too many * - confusing.

The pH values of L tea infusions were in the order: L-MIN > L-ALK, L-MAG > L-TAP. The pH values of T tea infusions were in the order: T-MIN > T-MAG, T-ALK, T-TAP. Even though the pH of original brewing waters of ALK was the highest (pH 8.64) as compared to other waters, it was L-MIN and T-MIN that showed the highest pH values. The pH of brewing water is one of the factors to be taken into account in maximizing the extraction yield from tea leaves [22,23]. A previous study suggested that the acidic condition enhanced the stability of catechins as the catechins might started to epimerize and degrade when the pH was greater than 6. The original pH values of TAP, MAG, and MIN were not significantly different from each other ($p > 0.05$) however were significantly lower ($p < 0.05$) than that of ALK.

For both tea brands used, pH of the MIN tea infusions was significantly the highest ($p < 0.05$) as compared to other infusions. According to Ref. [24]; low mineral content of brewing water lowered the pH of the infusion. Hence, this indicated that MIN might have higher mineral content among other brewing waters. Besides that, there was also a noticeable difference ($p < 0.05$) between the original pH and pH value of green tea infusion made with different brands of green tea. In general, the original pH value of four types of brewing waters were significantly higher ($p < 0.05$) than the pH value of tea infusion for both brand L and T green teas. This might be due to the difference in chemical composition between these two brands.

3.1.2. ORP analysis

The oxidation-reduction potential (ORP) measurements can be used as quality determinants for different types of evaluation such as water quality, degree of fermentation, oenological industry, and degree of maturation of wine [25]. In water quality analysis, ORP is used as an indication of possible contamination where water with an excess level of chlorine might be showing a large positive value [26].

Earlier research on the redox potential of drinking water suggested that water with a high concentration of chlorine and chlorine

Table 4
Total soluble solids (TSS) of tea infusions brewed with different brewing water and brands of green tea that expressed as brix concentration (°Brix), respectively.

Type of brewing water	Brand of green tea	
	L	T
TAP	0.97 0.06^{aA}	0.53 0.06^{bA}
ALK	0.900.00^{aA}	0.47 0.06^{bAB}
MAG	0.70 0.00^{aB}	0.53 0.06^{bA}
MIN	0.70 0.00^{aB}	0.40 0.00^{bB}

*TAP = Tap water; ALK = Alkaline ionized water; MAG = Magnetized water; MIN = Mineral water.
* Each value is expressed as mean value ± standard deviation (n = 3).
* a-b, within the same row, with different superscript letters are significantly different at $p < 0.05$ by Tukey's HSD.
* A-B, within the same column, with different superscript letter cases, are significantly different at $p < 0.05$ by Tukey's HSD.

dioxide added for sterilization were above equilibrium ORP level and this result demonstrated oxidative characteristics [26]. It was recommended to boil tap water as a means of dichlorination for domestic use. Based on the study conducted by Ref. [25]; the relationship between pH and ORP was investigated, and the authors reported that water having a reductive characteristic and pH ranging from weak acidity to weak alkalinity was more beneficial to the human body. There is no data of ORP values of green tea prepared with the water in questions, it may be desirable that a tea infusion that is great for human health should be in a reductive state, or less oxidative than the TAP.

Results of ORP of all the brewing water is shown in Table 2. The ORP values of these four types of brewing water were in descending order of TAP > MAG, MIN > ALK. ORP is usually negatively associated with pH, where the higher the pH, the lower the ORP. ALK, which had the highest pH (8.64) , showed the lowest ORP, whereas TAP, which had the lowest pH (6.49) showed the highest ORP. The results also indicated the effectiveness of the magnetizing and alkalinizing treatments as employed on MAG and ALK waters respectively in removing oxidizing compounds such as chlorine or chlorine dioxide.

3.1.3. Colour

Based on the colour results in Table 3, the L* value of tea samples brewed with MIN was significantly the lowest ($p < 0.05$) than other tea samples regardless of the brand of the tea. The results obtained were in accordance with previous studies in which green tea infusion prepared with MIN was darker green and colour intensity was higher than green tea infusion with TAP [10].

The a* value of all samples showed significant differences ($p < 0.05$) between brand of tea. Besides that, a* values of all samples were negative, and this indicated greenness in colour. Among all the samples, T-MIN showed the lowest a* values (−7.50), indicating that it had the darkest shade of green colour. This could be due to higher concentration of chlorophyll extracted in the sample [27–29].

Tea infusions with higher colour intensity indicate that the tea contained higher amounts of antioxidants such as polyphenolic molecules or flavonoids [30,31]. The b* of the samples varied from 24.61 ± 0.08^{bC} to 54.41 ± 0.04^{aA}. There was a significant difference ($p < 0.05$) of b* between types of the brewing water and brands of green tea. Tea infusions brewed with MIN showed the most intensive yellow, which was 54.41 ± 0.04^{aA} for L-MIN and 49.42 ± 0.07^{bA} for T-MIN. This might be due to MIN possesses greater extraction power on reducing sugar which caused browning [10]. [6] observed similar results on colour changes and suggested that these were due to hardness of the brewing water. Meanwhile, brand L green tea infusions had significantly higher ($p < 0.05$) b* values than brand T tea infusions. This might be because of differences in the chemical composition of tea.

For comparison in brewing waters, the h° angle of L-ALK was the highest (99.46) while T-MAG (101.53) was the highest (Table 3) for brand L and T respectively. Besides that, it could be corroborated that the tea infusions brewed using two different brands of green tea were significantly differed ($p < 0.05$) from one another. It was also noteworthy that the h° angle of all the samples ranged from 93.81 to 101.53. This showed that the colour of all the infusions were greenish yellow which supported the results of a* value.

3.1.4. Total soluble solids (TSS)

According to Ref. [32]; TSS are soluble solids in green tea that constitutes phenolic compounds, carbohydrates, alkaloids, pigments, amino acids, vitamins, and other minor compounds [33]. Soluble carbohydrates in green tea infusions maybe fructose, glucose, and sucrose which are responsible for the sweet taste of the brew. On the contrary, monosodium glutamate-like amino acids found in the brew are accountable for umami taste [34]. The amounts of extractable substances that are steeped into the tea brew is one of the important characteristics of green tea which determines the quality of green tea.

The TSS of the green tea infusions is summarized in Table 4. There was no clear trend in TSS of the infusions. The order of TSS for brand L was L-TAP, L-ALK > L-MAG, L-MIN. The order of TSS for brand T was L-TAP, L-MAG > L-ALK, L-MIN. The results showed that for brand L, TAP and ALK were more effective in extracting soluble solids than MAG and MIN. Meanwhile, for brand T, TAP and MAG were more effective than other brewing water. This finding was consistent with the previous findings obtained by Ref. [4] who reported that the TAP water extracted higher amounts of solids compared to pure water.

Consistently, MIN was the least effective in extracting the soluble solids as compared to other brewing waters. This result was in consistent with the work of [28]; thus suggesting that a high mineral content might negatively affect the extraction yield of green tea.

Table 5
Calcium concentration and sodium concentration of tea infusions brewed with different brewing water and brands of green tea that expressed in mg/L of infusions, respectively.

Analyses	Type of brewing water	Brand of green tea	
		L	T
Calcium	TAP	0.300.01^{bC}	0.340.00^{aC}
	ALK	0.250.00^{aD}	0.240.00^{bD}
	MAG	0.380.00^{bB}	0.390.00^{aB}
	MIN	0.490.00^{bA}	0.620.00^{aA}
Sodium	TAP	0.130.00^{bA}	0.150.00^{aD}
	ALK	0.010.00^{bD}	0.250.00^{aA}
	MAG	0.040.00^{bC}	0.230.00^{aC}
	MIN	0.070.00^{bB}	0.240.01^{aB}

* TAP = Tap water; ALK = Alkaline ionized water; MAG = Magnetized water; MIN = Mineral water.
* Each value is expressed as mean value ± standard deviation (n = 3).
* a-b, within the same row, with different superscript letters are significantly different at $p < 0.05$ by Tukey's HSD.
* A-D, within the same column, with different superscript letter cases are significantly different at $p < 0.05$ by Tukey's HSD.

This phenomenon could be due to the calcium uptake by leaves which complexed with pectin, causing a reduction in the element extraction [5,35]. TSS of all tea infusions prepared from brand L was significantly higher ($p < 0.05$) than that of brand T. This was due to different commercial tea manufacturers had different formulations, processing methods, packaging and suppliers which resulted a pronounced impact on TSS.

3.1.5. Mineral content

The mineral composition of green tea has always been one of the important quality attributes of tea brew since it could directly influence the sensory parameters of the tea [10,35]; Kim et al., 2012; 2016). It was established that minerals in brewing water can improve the taste of the green tea decoction due to the ability to extract the taste ingredients such as glutamic acids [5,10]. Water with high calcium and magnesium content is usually not preferable in making tea infusions. This was accorded with the findings from studies which suggested that high levels of mineral lowered the extractability of aluminum, total organic carbon, and polyphenols [28,36].

The results of calcium and sodium concentration in the green tea infusion are shown in Table 5. In this assay, two main minerals, calcium ions (Ca^{2+}) and sodium ions (Na^{+}) were selected because these two cations found in the infusions were critically influenced by the type of brewing water used as these ions were derived from the water instead of the tea leaves [22].

Type of brewing waters and green tea brands had a pronounced effect ($p < 0.05$) on the calcium and sodium content of tea infusion. The use of MIN to infuse green tea yielded the highest concentration of calcium in both the L-MIN and T-MIN [37]. reported that the calcium concentration of green tea infusion brewed with soft water, reverse osmosis water, packaged water, and ultrapure water were in the range of 0.150–0.566 mg/L. According to Ref. [32]; minerals like calcium ions (Ca^{2+}) in MIN affected colour of tea infusion in which Ca^{2+} promoted tea sediments and caused tea brews to show formation of scum and appeared to be darker and cloudy. This finding was accorded with the result of L* value (Table 3) in which L-MIN (84.34 ± 0.04^{bC}) and T-MIN (89.82 ± 0.29 ^{aD}) had the darkest colour.

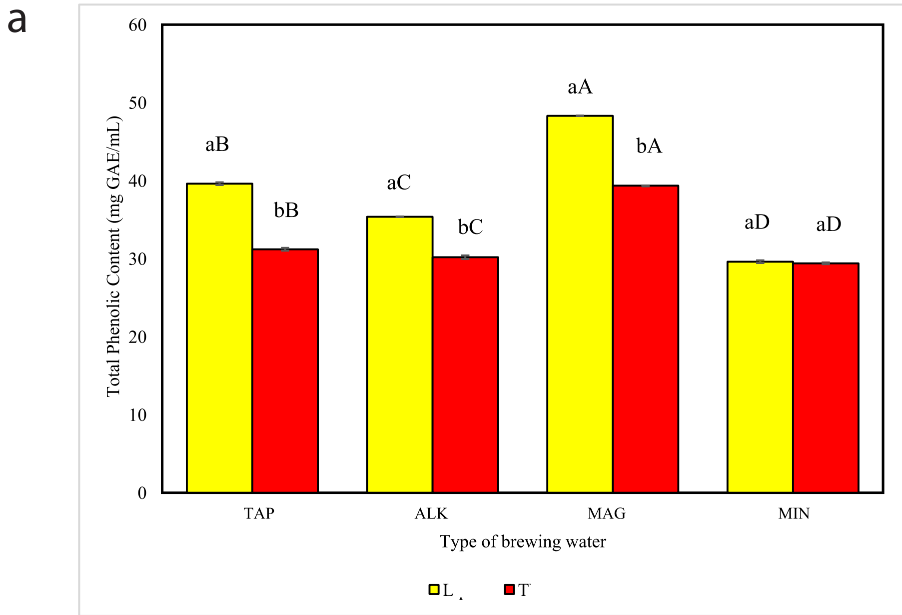
Impact of brewing water on calcium content of tea infusion was consistent for both types of green tea that could be ranked as followed: MIN > MAG > TAP > ALK. The Ca^{2+} ion in brewing water can interact with organic acids and induces the formation of undesirable tea cream and sediments. It was suggested that brewing water with a low amount of mineral content would have a greater advantage on the functional properties and storage stability of green tea [27]. The higher the mineralization of brewing water, the lower its permeability in the tea leaves. This resulted in negative influence on the extraction yield of polyphenols [35].

The brewing water used in steeping the green tea and brand of green tea also had an influence the amount of sodium. The concentration of sodium found in these samples were ranked from L-TAP > L-MIN > L-MAG > L-ALK. whereas for brand T green tea infusion, the sodium content ranked from T-ALK > T-MIN > T-MAG > T-TAP. Brand T green tea infusion consisted significantly higher ($p < 0.05$) amount of sodium than brand L green tea infusion regardless of the type of brewing water used. An interesting observation was the concentrations of calcium and sodium in L-MIN, T-MIN, L-MAG, and T-MAG. It was expected for L-MIN and T-MIN contain the highest minerals, but the fact that L-MAG and T-MAG to be ranked second highest might have something to do with the magnetizing treatments.

3.2. Antioxidant properties

3.2.1. Total phenolic compounds (TPC) and flavonoids content (FC)

Green tea is valued for its antioxidative compounds, therefore the TPC and FC of the tea infusions were compared. Based on Fig. 1, the order of TPC for both tea brands was MAG > TAP > ALK > MIN. On the other hand, the order of FC for brand L infusions was MAG > TAP > ALK > MIN, whereas FC for brand T infusions was MAG > MIN > TAP > ALK (Fig. 1b). The TPC and FC of both L-MAG and T-MAG were significantly the highest ($p < 0.05$) compared to others. MAG was more effective in extracting phenolic compounds or



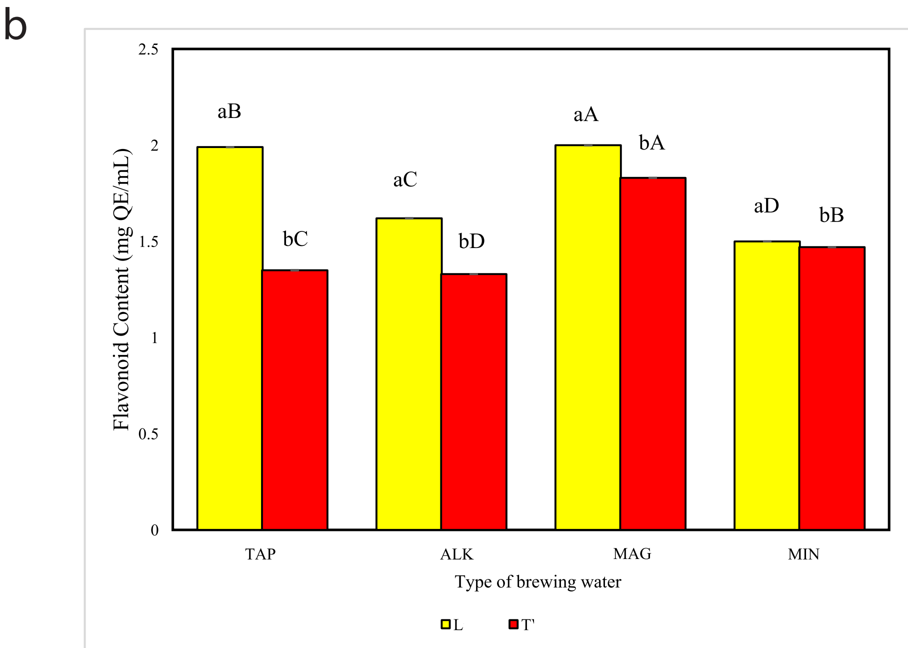


Fig. 1. a Total phenolic content (TPC) of tea infusions brewed with different brewing water (TAP, ALK, MAG, and MIN) and brands of green tea (L and T) that expressed in mg GAE/mL of infusions. b Flavonoid content (FC) of tea infusions brewed with different brewing water (TAP, ALK, MAG, and MIN) and brands of green tea (L and T) that expressed in mg QE/mL of infusions. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

flavonoids from the green tea leaves and showed a greater ability to dissolve nutrients compared to non-magnetic solvents [38]. This could be due to structural changes of water molecules occurred under magnetization and caused magnetic water to pass through plant cell membrane easily with its tiny and hexagonal structure [35]; Ali et al., 2014). Apart from that, it was suggested that water with a low structural viscosity due to small organic molecules can enhance the catechin content [4]. Based on the study conducted by Ref. [39]; calcium ions and magnesium ions in different types of brewing water enhanced antioxidant properties of green tea infusions via synergistic effect.

Table 6
2,2-diphenyl-1-picrylhydrazyl free radical scavenging activity (DPPH-SA) of tea infusions brewed with different brewing water and brands of green tea that expressed in percent (%) inhibition, respectively.

Analyses	Type of brewing water	Brand of green tea	
		L	T
DPPH	TAP	90.760.47^{bB}	93.070.15^{aA}
	ALK	90.540.62^{aB}	88.022.64^{bB}
	MAG	95.481.70^{aA}	93.060.11^{bA}
	MIN	76.710.81^{bC}	90.540.06^{aAB}

* TAP = Tap water; ALK = Alkaline ionized water; MAG = Magnetized water; MIN = Mineral water.
* Each value is expressed as mean value ± standard deviation (n = 3).
* a-b, within the same row, with different superscript letters are significantly different at $p < 0.05$ by Tukey's HSD.
* A-B, within the same column, with different superscript letter case are significantly different at $p < 0.05$ by Tukey's HSD.

Table 7
Hedonic test of green tea infusion.

Tea infusion	Appearance (colour)	Aroma	Flavour	Aftertaste	Astringency	Bitterness	Overall acceptability
T-TAP	5.53 1.11^{a}	5.071.28^{a}	4.801.35^{a}	4.871.36^{a}	4.801.30^{b}	5.13 1.04^{ab}	4.601.25^{b}
T-ALK	5.371.10^{a}	5.301.15^{a}	4.931.46^{a}	4.971.47^{a}	4.731.48^{b}	4.471.43^{b}	4.571.33^{b}
T-MAG	5.401.33^{a}	5.601.35^{a}	5.201.21^{a}	5.571.01^{a}	5.700.88^{a}	5.501.14^{a}	5.401.10^{a}
T-MIN	5.031.03^{a}	5.171.29^{a}	4.801.24^{a}	4.900.92^{a}	4.501.38^{b}	4.331.56^{b}	4.371.03^{b}

*TAP = Tap water; ALK = Alkaline ionized water; MAG = Magnetized water; MIN = Mineral water.
* Each value is expressed as mean value ± standard deviation (n = 3).
* a-b, within the same column, with different superscript letters are significantly different at $p < 0.05$ by Tukey's HSD.

3.2.2. Radical scavenging activity

The DPPH free radical scavenging activity of tea samples is reported in Table 6. The highest DPPH value was for L-MAG (95.48), whilst T-ALK showed the lowest ($p < 0.05$) values among the tea infusions. The antioxidants of green tea extract prepared using MAG were the most effective in terminating the propagation of free radicals and allowing the phenolic compounds to be a better hydrogen donor comparing to other tea extracts. It was reported that MAG could also generate oxygen anion molecules, causing it to possess radical scavenging ability [38]. This might explained the better performance of infusions brewed using MAG in DPPH assay. For scavenging ability on DPPH radicals, L-MIN demonstrated the lowest DPPH value among all the samples, which agreed with results obtained for TPC of MIN in this study.

Previous results of colour measurement (Table 3) seem to align with the results of DPPH-SA where T-MAG showed highest radical scavenging activity while the radical scavenging activity of L-MIN was the lowest. In addition, for the comparison of brands of teas, the DPPH value of L-MIN was significantly lower ($p < 0.05$) than that of T-MIN. This indicated MIN was the least suitable brewing water to be used in extracting polyphenolic compounds [24,27]. Similar report was also revealed by Ref. [40] in which the antioxidant capacity of the infusions was negatively associated with mineral concentration of the brewing water.

3.3. Hedonic test

[41] reported that characteristics of a high grade of green tea include smooth mouthfeel, least bitterness, and intense umami taste. Among all attributes tested, appearance and aroma of all green tea infusions scored more than 5. All infusions showed no significant difference ($p > 0.05$) for the sensory parameters of appearance, aroma, flavour, and aftertaste (Table 7). Compared to other tea infusions, T-MAG scored significantly highest ($p < 0.05$) in astringency. The scores of bitterness for T-MAG and T-TAP were similar but were higher than other infusions. Based on the study from Ref. [42]; the bitterness of tea was due to the bonding of unsaturated carbonyl groups of theacrine with the hydroxyl groups of other compounds via hydrogen bonds.

Probably due to the superior score in astringency, T-MAG was the only infusion that scored higher than 5 (acceptable) by the panelists and scored significantly highest ($p < 0.05$) in overall acceptability. Based on the finding reported by Ref. [43]; consumers prefer green tea with least bitter taste and astringency. The liking attributes of green tea included floral aroma and roasted grain flavour. Thus, green tea brewed in MAG appeared to have mild flavour and less bitter taste and was more accepted by consumers. It is known that the sensory properties of tea infusion that contained higher content of chemical constituents (e.g., flavonoids, phenolic acids, and alkaloids) is better perceived by consumers [44,45]. Hence, T-MAG which also had high radical scavenging activity and higher TPC scored the highest overall acceptability ($p < 0.05$) than other tea infusions.

4. Conclusion

The results of this study helped to identify the impact of brewing waters on qualities of tea infusion, which can contribute to the knowledge and selections of brewing water for tea consumers and manufacturers. Types of tea and brewing water had influences on qualities of green tea infusions. It appeared that MAG might be the most superior brewing water among the four types of waters in extracting green tea and this indicated that it had a greater ability to dissolve nutrients compared to non-magnetic solvents. Both L-MAG and T-MAG marked the highest concentration in TPC, FC, and DPPH assay. These results showed that green tea infusion with MAG was able to terminate the propagation of free radicals and allowing the phenolic compounds to be a better hydrogen donor comparing to other tea extracts. T-MAG was the brightest ($94.520.23^{aA}$) and most greenish yellow ($-5.020.06^{aC}$) among all green tea infusions. On top of that, results from hedonic test showed that T-MAG had the highest overall acceptability ($5.401.10^{a}$) by panelists as it appeared to have mild flavour and less bitter taste. The limitation of this study included it was based on only one type of tea, green tea. Other types of teas such as black tea, white tea, oolong tea, and so on were not evaluated in this study.

Author statement

Hui-Ling Tan: Investigation, Methodology, Writing-original draft. **Le-Xuan Lee:** Investigation, Methodology. **Azhar Mat Easa and Ojukwu-Moses:** Writing - review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Azhar Mat Easa reports financial support was provided by Ministry of Higher Education Malaysia. Tan Hui Ling reports financial support was provided by Universiti Sains Malaysia.

Acknowledgment

This work was supported by the Ministry of Higher Education Malaysia for Prototype Research Grant Scheme with project code (PRGS/1/2022/TK02/USM/01/1).

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.heliyon.2022.e12638.

References

[1] V. Gianfredi, D. Nucci, A. Abalsamo, M. Acito, M. Villarini, M. Moretti, S. Realdon, Green tea consumption and risk of breast cancer and recurrence—a systematic review and meta-analysis of observational studies, Nutrients 10 (12) (2018) 1886.
[2] E. Sharpe, F. Hua, S. Schuckers, S. Andreescu, R. Bradley, Effects of brewing conditions on the antioxidant capacity of twenty-four commercial green tea varieties, Food Chem. 192 (2016) 380–387.
[3] Z. Danrong, C. Yuqiong, N. Dejiang, Effect of water quality on the nutritional components and antioxidant activity of green tea extracts, Food Chem. 113 (1) (2009) 110–114.
[4] H. Zhang, Y. Jiang, Y. Lv, J. Pan, Y. Duan, Y. Huang, Y. Zhu, S. Zhang, K. Geng, Effect of water quality on the main components in Fuding white tea infusions, J. Food Sci. Technol. 54 (2017) 1206–1211.
[5] M. Franks, P. Lawrence, A. Abbaspourrad, R. Dando, The influence of water composition on flavor and nutrient extraction in green and black tea, Nutrients 11 (1) (2019) 80.
[6] M. Cabrera, F. Taher, A. Llantada, Q. Do, T. Sapp, M. Sommerhalter, Effect of water hardness on catechin and caffeine content in green tea infusions, Molecules 26 (12) (2021).
[7] E.Q. Jassim, C.H. Aqeel, Effect of alkaline water and/or magnetic water on some physiological characteristic in broiler chicken, Journal of Entomology and Zoology Studies 5 (5) (2017) 1643–1647.
[8] Y. Tanaka, Y. Saihara, K. Izumotani, H. Nakamura, Daily ingestion of alkaline electrolyzed water containing hydrogen influences human health, including gastrointestinal symptoms, Med. Gas Res. 8 (4) (2018) 160–166.
[9] A. Elaoud, N. Turki, H. Ben Amor, R. Jalel, N.B. Salah, Influence of the magnetic device on water quality and production of melon, International Journal of Current Engineering and Technology 6 (6) (2016) 2256–2260.
[10] D. Houri, S.I. Yoshioka, K. Matsumoto, K. Amikawa, S. Tanaka, N. Nagata, Elements and physical properties of green tea decoction using Hakusan-Meisui mineral water, Yonago Acta Med. 51 (3) (2008) 61–67.
[11] S.Y. Cao, C.N. Zhao, R.Y. Gan, X.Y. Xu, X.L. Wei, H. Corke, A.G. Atanasov, H.B. Li, Effects and mechanisms of tea and its bioactive compounds for the prevention and treatment of cardiovascular diseases: an updated review, Antioxidants 8 (6) (2019) 166.
[12] H. Han, H. Wang, G. Gao, P. Rao, J. Zhou, L. Ke, Y. Xu, pH effect on colloidal characteristics of micro-nano particles in lapsang souchong black tea infusion, Food Control 133 (2022), 108643.
[13] D.D. Chapman, V. Kimstach, Selection of water quality variables, in: D. Chapman (Ed.), Water Quality Assessments - a Guide to Use of Biota, Sediments and Water in Environmental Monitoring, second ed., E&FN Spon, an imprint of Chapman & Hall, Cambridge, 1996, pp. 74–133.
[14] Y. Liu, L. Luo, C. Liao, L. Chen, J. Wang, L. Zeng, Effects of brewing conditions on the phytochemical composition, sensory qualities and antioxidant activity of green tea infusion: a study using response surface methodology, Food Chem. 269 (2018) 24–34.
[15] The Association of Official Agricultural (Aoac), Official Method of Analysis, seventeenth ed., AOAC, Washington, DC, USA, 2000, 2000.
[16] S. Nookabkaew, N. Rangkadilok, J. Satayavivad, Determination of trace elements in herbal tea products and their infusions consumed in Thailand, J. Agric. Food Chem. 54 (18) (2006) 6939–6944.
[17] L. Fu, B.T. Xu, R.Y. Gan, Y. Zhang, X.R. Xu, E.Q. Xia, H.B. Li, Total phenolic contents and antioxidant capacities of herbal and tea infusions, Int. J. Mol. Sci. 12 (4) (2011) 2112–2124.
[18] T. Amin, H.R. Naik, S.Z. Hussain, A. Jabeen, M. Thakur, In-vitro antioxidant and antibacterial activities of pumpkin, quince, muskmelon and bottle gourd seeds, J. Food Meas. Char. 12 (1) (2018) 182–190.

[19] M. Majeed, S. Majeed, K. Nagabhushanam, S. Arumugam, K. Beede, F. Ali, Evaluation of probiotic *Bacillus coagulans* MTCC 5856 viability after tea and coffee brewing and its growth in GIT hostile environment, Food Res. Int. 121 (2019) 497–505.

[20] M. Viljoen, M. Muller, D. De Beer, E. Joubert, Identification of broad-based sensory attributes driving consumer preference of ready-to-drink rooibos iced tea with increased aspalathin content, South Afr. J. Bot. 110 (2017) 177–183.

[21] L. Li, J. Lu, H. Pang, Z. Zhang, J. Yang, P. Li, M. Fan, New insight into scale inhibition during tea brewing: $Ca2+/Mg2+$ complexing and alkalinity consumption, J. Environ. Sci. 124 (2023) 901–914.

[22] Y.Q. Xu, C. Zou, Y. Gao, J.X. Chen, F. Wang, G.S. Chen, J.F. Yin, Effect of the type of brewing water on the chemical composition, sensory quality, and antioxidant capacity of Chinese teas, Food Chem. 236 (2017) 142–151.

[23] Q.V. Vuong, J.B. Golding, C.E. Stathopoulos, P.D. Roach, Effects of aqueous brewing solution pH on the extraction of the major green tea constituents, Food Res. Int. 53 (2) (2013) 713–719.

[24] K. Fibrianto, A.D. Ardianti, K. Pradipta, W.B. Sunarharum, The influence of brewing water characteristic on sensory perception of pour-over local coffee, IOP Conf. Ser. Earth Environ. Sci. 102 (2018), 012095.

[25] P.C. Chen, F.S. Chang, I.Z. Chen, F.M. Lu, T.J. Cheng, R.L.C. Chen, Redox potential of tea infusion as an index for the degree of fermentation, Anal. Chim. Acta 594 (1) (2007) 32–36.

[26] C.N. James, R.C. Copeland, D.A. Lytle, Relationships between Oxidation-Reduction Potential, Oxidant, and pH in Drinking Water. Proc. 2004, AWWA WQTC, San Antonio, Texas, 2004.

[27] J. Li, H.J. Joung, I.W. Lee, X. Chen, H.J. Park, The influence of different water types and brewing durations on the colloidal properties of green tea infusion, Int. J. Food Sci. Technol. 50 (11) (2015) 2483–2489.

[28] A. Mossion, M. Potin-Gautier, S. Delerue, I. Le Hécho, P. Behra, Effect of water composition on aluminium, calcium and organic carbon extraction in tea infusions, Food Chem. 106 (2008) 1467–1475.

[29] J. Ryu, M.J. Kim, J.H. Lee, Extraction of green tea phenolics using water bubbled with gases, J. Food Sci. 84 (6) (2019) 1308–1314.

[30] M. Schwarz, M.C. Rodríguez, D.A. Guillén, C.G. Barroso, Evolution of the colour, antioxidant activity and polyphenols in unusually aged Sherry wines, Food Chem. 133 (2) (2012).

[31] D.N. Fatanah, N. Abdullah, N. Hashim, A. Abd Hamid, Antioxidant activity, colour, and mineral content of herbal tea prepared from *Cosmos caudatus* leaves at different maturity stages, Malaysian Journal of Analytical Science 20 (3) (2016) 607–617.

[32] M.J. Kim, S.S. Kim, S.I. Lee, Quality characteristics and content of polysaccharides in green tea fermented by, Monascus pilosus. Preventive Nutrition and Food Science 17 (4) (2012) 293–298.

[33] Y. Kim, K.G. Lee, M.K. Kim, Volatile and non-volatile compounds in green tea affected in harvesting time and their correlation to consumer preference, J. Food Sci. Technol. 53 (10) (2016) 3735–3743.

[34] S.D. Lin, P. Udompornmongkol, J.H. Yang, S.Y. Chen, J.L. Mau, Quality and antioxidant property of three types of tea infusions, J. Food Process. Preserv. 38 (4) (2014).

[35] W.Y. Huang, Y.R. Lin, R.F. Ho, H.Y. Liu, Y.S. Lin, Effects of water solutions on extracting green tea leaves, Sci. World J. (2013), 368350, 2013.

[36] V.S.P. Chaturvedula, I. Prakash, The aroma, taste, color, and bioactive constituents of tea, J. Med. Plants Res. 5 (11) (2011) 2110–2124.

[37] C.S. Murugesh, J.B. Manoj, D.J. Haware, R. Ravi, R. Subramanian, Influence of water quality on nutritional and sensory characteristics of green tea infusion, J. Food Process. Eng. 40 (5) (2017), e12532.

[38] M.S. Al-Nimer, S.M. Al-Deen, Z.W.A. Abdul Lateef, I.T. Al-Kayar, Magnetized water induces changes in the antioxidant properties of some medicinal plants extracts, Int. J. Green Pharm. 5 (2) (2011) 145–148.

[39] Q.Q. Cao, Y.Q. Fu, C.B. Zhang, Y. Zhu, J.F. Yin, D. Granato, Y.Q. Xu, Effect of brewing water on the antioxidant capacity of green tea infusion with DPPH assay, J. Chem. 2022 (2022).

[40] J. Wyrostek, R. Kowalski, The effect of water mineralization on the extraction of active compounds from selected herbs and on the antioxidant properties of the obtained brews, Foods 10 (6) (2021) 1227.

[41] J.H. Ye, Y. Ye, J.F. Yin, J. Jin, Y.R. Liang, R.Y. Liu, Y.Q. Xu, Bitterness and astringency of tea leaves and products: formation mechanism and reducing strategies, Trends Food Sci. Technol. 123 (2022) 130–143.

[42] Y. Shi, S.R. Zhang, K. Sun, X.H. Wang, J.L. Jiang, L. Zeng, Characterization of bitter taste theacrine in Pu-erh tea, J. Food Compos. Anal. 106 (2022), 104331.

[43] S.M. Lee, H.S. Lee, K.H. Kim, K.O. Kim, Sensory characteristics and consumer acceptability of decaffeinated green teas, J. Food Sci. 74 (3) (2009) S135–S141.

[44] M. Adnan, A. Ahmad, A. Ahmed, N. Khalid, I. Hayat, I. Ahmed, Chemical composition and sensory evaluation of tea (Camellia sinensis) commercialized in Pakistan, Pakistan J. Bot. 45 (3) (2013) 901–907.

[45] S.H. Chiang, M.F. Tsou, C.Y. Chang, C.W. Chen, Physicochemical characteristics, sensory quality, and antioxidant properties of Paochung tea infusion brewed in cold water, Int. J. Food Prop. 23 (1) (2020) 1611–1623.

[46] S.D. Lin, J.H. Yang, Y.J. Hsieh, E.H. Liu, J.L. Mau, Effect of different brewing methods on quality of green tea, J. Food Process. Preserv. 38 (3) (2014) 1234–1243.