RESEARCH ARTICLE

Effect of Water Types on the Chemical Properties and Taste in Brewing Tea Soups

Teow C. Teoh[1*], Ee H. Tan[2], Wei H. B. Tan[2], Kai F. Low[2]

Abstract

The ancient Chinese proverb says, water is the "mother of tea", implying that water plays an important role in brewing tea soups. In this study, the pH, total dissolved solids (TDS) and electrical conductivity (EC) of four types of water, i.e., alkaline water (A), mineral water (M), reverse osmosis water (R), and distilled water (D) were determined. Then, the four types of water, A, M, R, and D were used to brew two types of tea leaves, a white tea and a Pu'er ripe tea, and the pH, TDS and EC of the resulting tea soups were determined for three consecutive brewing intervals of 2, 4 and 6 minutes, respectively. In addition, survey data of tasting the tea soups were collected from a total of 17 respondents for the tea soups brewed by the four types of water, A, M, R and D, respectively. The results showed that A and M were alkaline before brewing tea soups, while the pH of R and D were slightly acidic. However, upon the three consecutive brewing of tea leaves, for white tea, the pH was neutralized by A and M, while R and D remained acidic. For Pu'er ripe tea, the pH was slightly acidic after the brewing by all the water types of A, M, R and D. The TDS for white tea was increased during the second brewing for A and M, and the TDS was decreased in the third brewing for all types of water. For Pu'er ripe tea, the TDS decreased gradually upon three consecutive brewing for all types of water. In general, for the taste of tea soups, the rating scores of 4 and 5 were dominated by alkaline water (A) for both white tea and Pu'er tea. For rating scores of 3, it was dominated by mineral water (M) and reverse osmosis water (R) for both white tea and Pu'er tea. In conclusion, alkaline water (A) appeared to be the preferred water type for brewing tea soups.

Keywords: Water types, White tea, Pu'er ripe tea, Chemical parameters, Tasting.

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INTRODUCTION

Tea is a necessary beverage for every household in the world, and the products of the tea tree [*Camellia sinensis* (L.) O. Kuntze] are also important economic commodities for a country. In China, the annual consumption of tea has exceeded 2 million tons, and the demand of water for brewing tea exceeds 200 million tons in China, for which the value of water used for tea brewing can reach 400 billion yuan, attracting the attention of a large number of water companies.[1] Tea is a nutritional beverage rich in polyphenols, catechins, minerals, dietary fiber and other nutrients.[2] Water exhibits a significant role in the color, aroma, taste and chemical properties of the tea soup, rendered it as the "mother of tea". In general, the pH of tea infusions was found to be acidic.[3] It can be noted that the pH values of tea infusions were lower than those of the original water used to brew the teas, possibly due to extraction of chemicals such as amino acids, phenols and organic acids.[4-6] The measuring of pH of teas by using a pH meter indicates that teas, especially Chinese teas without additional ingredients, are mainly acidic, helps to bust the myth of the traditional beliefs among the majority of Chinese communities who conventionally believe that Chinese teas are alkaline because the taste is bitter.

The release of non-volatile substances such tea polyphenols, caffeine, amino acids, mineral elements, and tea aromatic components are all directly influenced by the brewing process. The brewing time, temperature, and tea-to-water ratio are commonly correlated positively to the content of tea flavour compounds. The dissolution rate of mineral substances such as Ca^{2+}, $Mg^{2+}$and Fe^{3+} varied greatly depending on the water type used.[7] Commonly, mineral water, distilled water, tap water, natural mineral water, and mountain spring water can be used to brew tea soups.[4,7] A previous study showed that mineral-rich water weakens both flavor profiles and decreases tea infusions' catechin contents and antioxidant capacity.[4] Tea soups brewed from reverse osmotic water had better flavor quality.[8] It has been reported that Fe^{2+} in water induced aroma deterioration of green tea infusion with heat treatment.[9] The tea infusions brewed in water with alkaline pH and total dissolved solids (TDS >140 ppm) generally had a darker color and lower overall taste acceptability due to HCO^{3-}, Ca^{2+} and Mg^{2+} ions, resulting in lower antioxidant capacity. Teas brewed with higher pH/TDS water were more rapidly oxidized, resulting in a darker color due to polymerization of catechins when exposed to the air. Hence, it was suggested that low mineral brewing water was better for Chinese tea, both from the taste and health benefit perspectives.[10, 11]

Water types is a crucial factor affecting the pH, total dissolved solids, color, taste and aroma of tea soups.[4, 7, 10] In this study, four types of water, namely alkaline water (A), mineral water (M), reverse osmosis water (R), and distilled water (D) were chosen as representative of the different drinking waters available for brewing tea, while two types of Chinese teas used were a white tea and a Pu'er ripe tea. Alkaline water was artificially produced by using a K brand water machine, while reverse osmosis and distilled waters were processed by artificial methods using hollow membranes and the distillation process, respectively. Mineral water was obtained from

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a natural fountain source located in Taiping, Perak State, Malaysia. Consequently, this study's results will guide the optimal choice of brewing water types for both tea manufacturers and consumers.

Materials And Methods

The test materials were white tea (Shou Mei) and Pu'er ripe tea provided by the Kuala Lumpur Tea Art Society (KLTA) in Malaysia, as well as a 150cc brewing cup, tea bowl and bancha tray made of pure white porcelain. Four types of water, namely alkaline water (A), mineral water (M), reverse osmosis water (R) and distilled water (D), were purchased from local convenience stores. A multifunctional water quality tester (model: EZ-9909SP) was purchased from a local dealer Wulibuy Sdn Bhd, Selangor, Malaysia.

Brewing of Tea Soups

The international standard "appraisal cup" was used to identify the quality of tea. It was composed of a brewing cup, tea bowl and bancha tray, all made of pure white porcelain. The brewing cup was 150cc. When using, 3 grams of tea leaves were poured into a brewing cup. Then boiling hot water was poured into it, it was covered, and soaked for three times in a row. The brewing intervals were 2, 4 and 6 minutes, respectively. Then, the tea soup was poured into the tea bowl. The drinking water was first coded, and the samples were placed in a row on the tea tray. The brewing cups, tea bowls, and residue trays were in front of the tea tray. The tasting of the tea soup was based on blind testing. A total of 17 respondents from KLTA were invited to rate the tea soups based on factors including observing the color of the soup, smelling the heat and aroma, and commenting on the taste. Finally, the tea soup tasting adopted a scoring system of 1 to 5 points, with the highest score being 5 points and the lowest score being 1 point.

Chemical Parameter Determination

A multifunction water quality tester (Model Number: EZ-9909SP) was used to measure the pH, total dissolved solids (TDS) and electrical conductivity (EC) of four types of water, i.e. alkaline water (A), mineral water (M), reverse osmosis water (R), and distilled water (D) at 25°C. Then, the tea soups' pH, total dissolved solids (TDS) and electrical conductivity (EC) with brewing intervals of 2 minutes, 4 minutes and 6 minutes were also measured at 25°C. The results were recorded as an average of three replicates.

Statistical Analysis

Recorded data were subjected to analysis of mean, standard deviation and single factor variance (ANOVA) using Microsoft Excel 2016. The significant level was set at $p < 0.05$ for single-factor ANOVA.

Results

The pH of Tea Soups

The pH of alkaline water (A) and mineral water (M) was alkaline at pH 9.8 ± 0.1 and 8.1 ± 0.2, respectively. On the other hand, the pH of reverse osmosis water (R) and distilled water (D) was nearly neutral at pH 6.6 ± 0.1 and 6.9 ± 0.1, respectively, as shown in Figure 1.

The total dissolved solids (TDS) of alkaline water (A) was lower than that of mineral water (M) at 56.3 ± 0.6 and 151.7 ± 0.6 ppm, respectively. In contrast, the TDS of reverse osmosis water (R) and distilled water (D) was almost zero at 3.0 ± 0.1 and 0.5 ± 0.1 ppm, respectively, as shown in Figure 2. Therefore, reverse osmosis and distilled water are very pure water types.

The pH of tea soups for white tea (WT) brewed with distilled water (D+WT) (red broken line is distilled water (D) only and red line is distilled water brewed with white tea (D+WT)) remained acidic after the three consecutive brewing intervals of 2, 4 and 6 minutes, respectively. Similarly, the pH for reverse osmosis water and white tea (R+WT) (yellow lines) was acidic at pH 5~6. However, the pH for alkaline water brewed with white tea (A+WT) (blue line) and mineral water brewed with white tea (M+WT) (green line) was nearly neutral at pH ~7, as shown in Figure 3. Single-factor ANOVA results showed that the difference between groups of pH for white tea was significantly different at $p < 0.05$.

The pH of tea soups for Pu'er tea (PT) brewed with distilled water (D+PT) (red broken line is distilled water (D) only and red line is distilled water brewed with Pu'er tea (D+PT)) was slightly acidic after the three consecutive brewing intervals of 2, 4 and 6 minutes, respectively. Similarly, the pH for reverse osmosis water and Pu'er tea (R+PT) (yellow lines) was slightly acidic at pH ~6. However, the pH for alkaline water brewed with Pu'er tea (A+PT) (blue line) and mineral water brewed with Pu'er tea (M+PT) (green line) was nearly neutral at pH ~7, as shown in Figure 4. Single-factor ANOVA results showed that the difference between groups of pH for Pu'er tea was significantly different at $p < 0.05$.

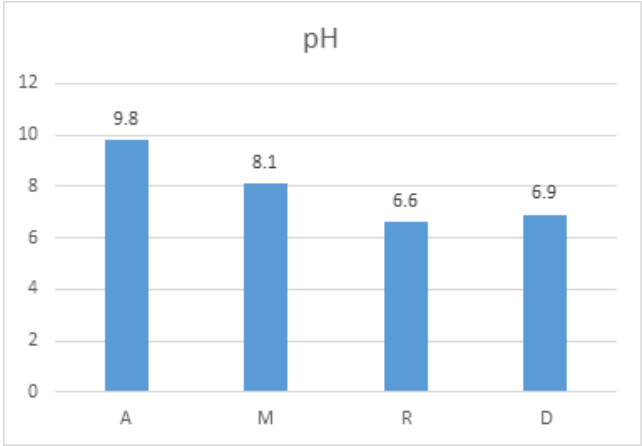

Figure 1: The pH for four types of water, namely alkaline water (A), mineral water (M), reverse osmosis water (R), and distilled water (D)

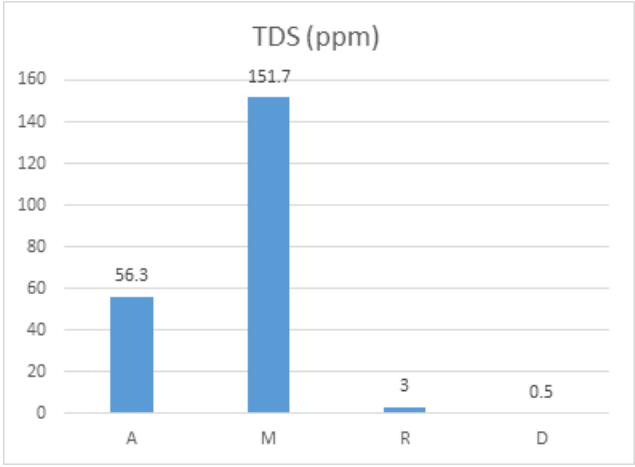

Figure 2: The TDS for four types of water, namely alkaline water (A), mineral water (M), reverse osmosis water (R), and distilled water (D)

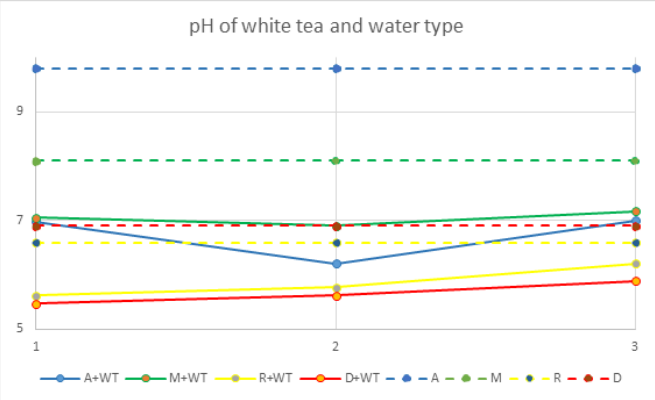

Figure 3: The pH for four types of water, namely alkaline water (A) (blue broken line), mineral water (M) (green broken line), reverse osmosis water (R) (yellow broken line), and distilled water (D) (red broken line); and alkaline water with white tea (A+WT) (blue line), mineral water with white tea (M+WT) (green line), reverse osmosis water with white tea (R+WT) (yellow line) and distilled water with white tea (D+WT) (red line)

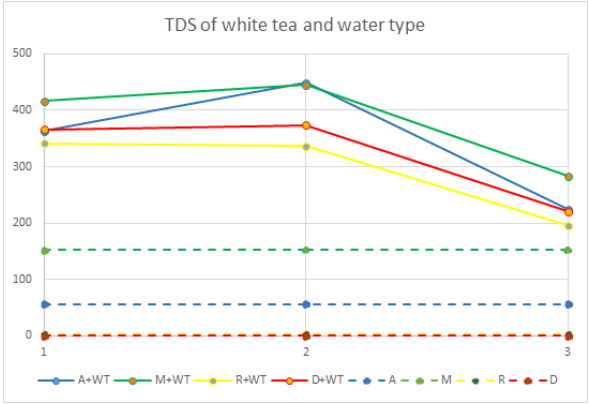

Figure 5: The TDS for four types of water, namely alkaline water (A) (blue broken line), mineral water (M) (green broken line), reverse osmosis water (R) (yellow broken line), and distilled water (D) (red broken line); and alkaline water with white tea (A+WT) (blue line), mineral water with white tea (M+WT) (green line), reverse osmosis water with white tea (R+WT) (yellow line) and distilled water with white tea (D+WT) (red line)

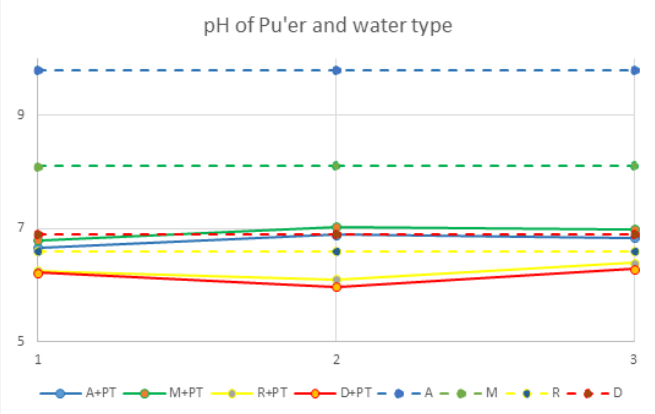

Figure 4: The pH for four types of water, namely alkaline water (A) (blue broken line), mineral water (M) (green broken line), reverse osmosis water (R) (yellow broken line), and distilled water (D) (red broken line); and alkaline water with Pu'er tea (A+PT) (blue line), mineral water with Pu'er tea (M+PT) (green line), reverse osmosis water with Pu'er tea (R+PT) (yellow line) and distilled water with Pu'er tea (D+PT) (red line)

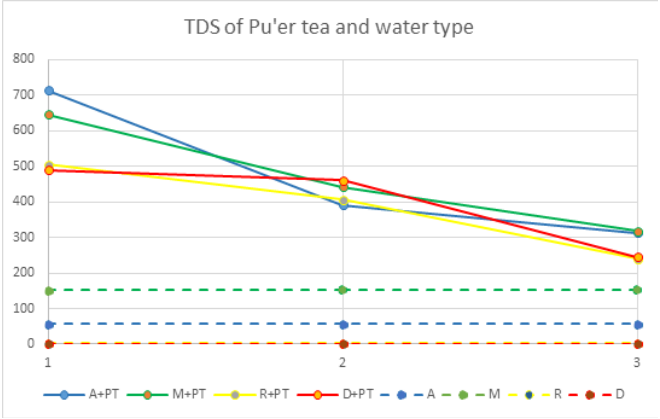

Figure 6: The TDS for four types of water, namely alkaline water (A) (blue broken line), mineral water (M) (green broken line), reverse osmosis water (R) (yellow broken line), and distilled water (D) (red broken line); and alkaline water with Pu'er tea (A+PT) (blue line), mineral water with Pu'er tea (M+PT) (green line), reverse osmosis water with Pu'er tea (R+PT) (yellow line) and distilled water with Pu'er tea (D+PT) (red line)

The TDS of Tea Soups

The total dissolved solids (TDS) of white tea brewed with all the water types of alkaline water (A+WT), mineral water (M+WT), reverse osmosis water (R+WT) and distilled water (D+WT) (blue, green, yellow and red lines, respectively) was decreasing from 400 to 200 ppm after three consecutive brewing intervals of 2, 4 and 6 minutes, respectively. Single-factor ANOVA results showed that the difference between groups of TDS for white tea was not significant at $p = 0.69$ ($p > 0.05$) as shown in Figure 5.

The total dissolved solids (TDS) of Pu'er tea brewed with all the water types of alkaline water (A+PT), mineral water (M+PT), reverse osmosis water (R+PT) and distilled water (D+PT) (blue, green, yellow and red lines, respectively) was decreasing from 700 to 300 ppm after three consecutive brewing intervals of 2, 4 and 6 minutes, respectively. Single-factor ANOVA results showed that the difference between groups of TDS for Pu'er tea was not significant at $p = 0.89$ ($p > 0.05$) as shown in Figure 6.

As shown in Table 1, water types R and D can extract more TDS from white tea, followed by A and then M. However, alkaline water (A) can extract the highest TDS from white tea in the second brewing of 4 minutes at 393 ppm of TDS. For Pu'er tea, the highest TDS was from alkaline water (A) at 658 ppm in the first brewing of 2 min, followed by water types R and D, while the lowest TDS was from water type M (Table 2).

The EC of Tea Soups

The electrical conductivity (EC) of white tea brewed with all the water types of alkaline water (A+WT), mineral water (M+WT), reverse osmosis water (R+WT) and distilled water (D+WT) (blue, green, yellow and red lines, respectively) was decreasing from 900 to 400 µS/cm after three consecutive brewing intervals of 2, 4 and 6 minutes, respectively. Single-factor ANOVA results showed that the difference between groups of EC for white tea was not significant at $p = 0.69$ ($p > 0.05$) as shown in Figure 7. This result's trend is similar to that of TDS.

Table 1: Total dissolved solids (TDS) and net TDS for white tea soups with respect to the brewing intervals of 2 min, 4 min and 6 min by the four types of water namely, alkaline water (A), mineral water (M), reverse osmosis water (R) and distilled water (D). The total dissolved solids (TDS) of white tea brewed with alkaline water (A+WT), mineral water (M+WT), reverse osmosis water (R+WT) and distilled water (D+WT)

Parameters	*Total TDS (ppm)*			*Net TDS (ppm)*		
Tea soup	*Brewing 2 minutes*	*Brewing 4 minutes*	*Brewing 6 minutes*	*Brewing 2 minutes*	*Brewing 4 minutes*	*Brewing 6 minutes*
A+WT	363	449	224	307	393*	168
M+WT	417	445	283	265	293	131
R+WT	341	337	196	338	334	193
D+WT	366	374	221	366	374	221

A = alkaline water, M = mineral water, R = reverse osmosis water, D = distilled water, WT = white tea, * = highest TDS

Table 2: Total dissolved solids (TDS) and net TDS for Pu'er tea soups with respect to the brewing intervals of 2 min, 4 min and 6 min by the four types of water namely, alkaline water (A), mineral water (M), reverse osmosis water (R) and distilled water (D). The total dissolved solids (TDS) of Pu'er tea brewed with alkaline water (A+PT), mineral water (M+PT), reverse osmosis water (R+PT) and distilled water (D+PT)

Parameters	*Total TDS (ppm)*			*Net TDS (ppm)*		
Tea soup	*Brewing 2 minutes*	*Brewing 4 minutes*	*Brewing 6 minutes*	*Brewing 2 minutes*	*Brewing 4 minutes*	*Brewing 6 minutes*
A+PT	714	391	313	658*	335	257
M+PT	646	443	318	494	291	166
R+PT	505	407	241	502	404	238
D+PT	490	461	245	490	461	245

A = alkaline water, M = mineral water, R = reverse osmosis water, D = distilled water, WT = white tea, * = highest TDS

The electrical conductivity (EC) of Pu'er tea brewed with all the water types of alkaline water (A+PT), mineral water (M+PT), reverse osmosis water (R+PT) and distilled water (D+PT) (blue, green, yellow and red lines, respectively) was decreasing from 1400 to 500 µS/cm after three consecutive brewing intervals of 2, 4 and 6 minutes, respectively. Single-factor ANOVA results showed that the difference between groups of EC for Pu'er tea was not significant at $p = 0.87$ ($p > 0.05$) as shown in Figure 8. This result's trend is similar to that of TDS.

The Rating Scores of Tea Soups

The number of responses of the rating of white tea and Pu'er tea with respect to the four types of water, A, M, R and D are shown in Figures 9 and 10. In general, the results show that the rating scores of 4 and 5 were dominated by alkaline water (A) at 25 and 27 responses for both white tea and Pu'er tea, for the combination of A+WT and A+PT, respectively. For rating scores of 3, i.e. the average rating score, it was dominated by mineral water (M) and reverse osmosis water (R) with the number of responses of 20~27 for both white tea and Pu'er tea.

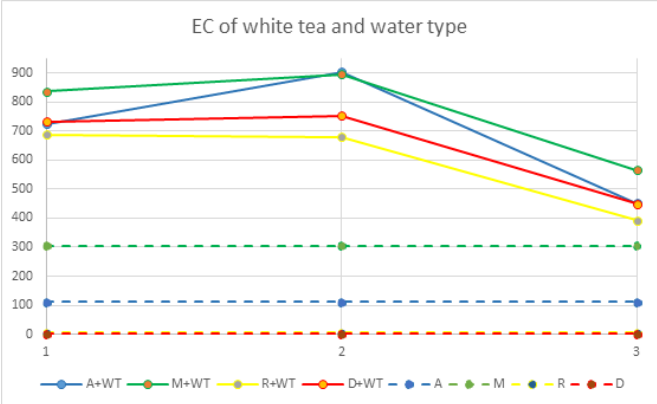

Figure 7: The EC for four types of water, namely alkaline water (A) (blue broken line), mineral water (M) (green broken line), reverse osmosis water (R) (yellow broken line), and distilled water (D) (red broken line); and alkaline water with white tea (A+WT) (blue line), mineral water with white tea (M+WT) (green line), reverse osmosis water with white tea (R+WT) (yellow line) and distilled water with white tea (D+WT) (red line)

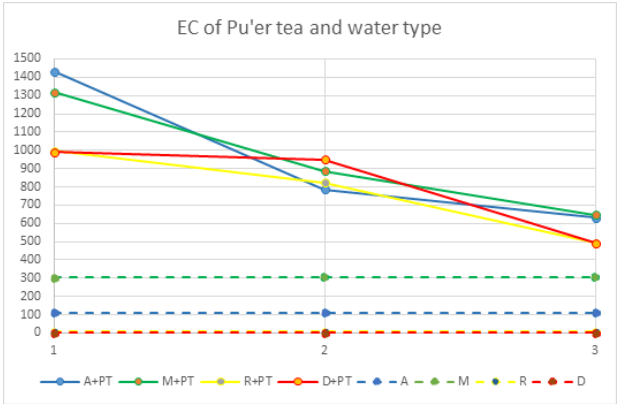

Figure 8: The EC for four types of water, namely alkaline water (A) (blue broken line), mineral water (M) (green broken line), reverse osmosis water (R) (yellow broken line), and distilled water (D) (red broken line); and alkaline water with Pu'er tea (A+PT) (blue line), mineral water with Pu'er tea (M+PT) (green line), reverse osmosis water with Pu'er tea (R+PT) (yellow line) and distilled water with Pu'er tea (D+PT) (red line)

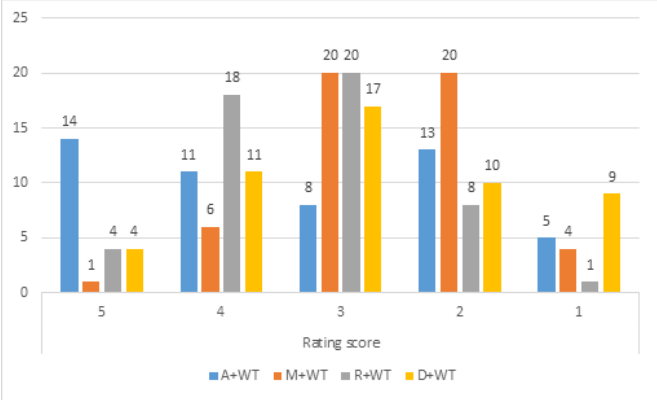

Figure 9: The number of responses of rating score from 1 to 5 for four types of water, namely alkaline water with white tea (A+WT) (blue), mineral water with white tea (M+WT) (orange), reverse osmosis water with white tea (R+WT) (grey) and distilled water with white tea (D+WT) (yellow).

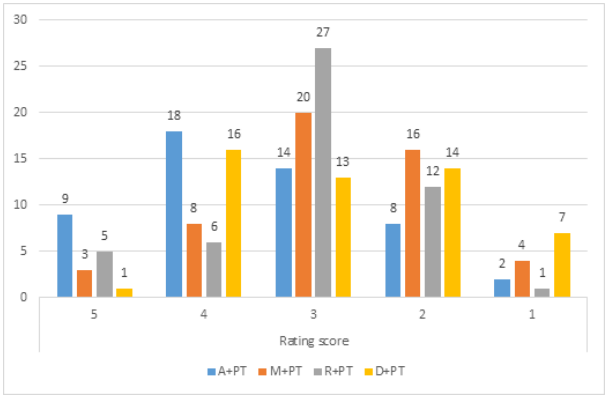

Figure 10: The number of responses of rating score from 1 to 5 for four types of water, namely alkaline water with Pu'er tea (A+PT) (blue), mineral water with Pu'er tea (M+PT) (orange), reverse osmosis water with Pu'er tea (R+PT) (grey) and distilled water with Pu'er tea (D+PT) (yellow).

Discussion

Although Chinese teas taste bitter, but the results from this and other studies showed that Chinese teas were acidic.[5, 7] The pH of water is determined by the mineral ions such as Ca^{2+}, K^{+} and Mg^{2+} that dissolved in the types of water, whereby the pH of alkaline water and mineral water was basic, whereas reverse osmosis and distilled water were neutral water types (Figure 1). Our results showed that the total dissolved solids (TDS) of mineral water (M) was three times higher than that of alkaline water (A), while the TDS of reverse osmosis (R) and distilled waters (D) was almost negligible (Figure 2). Previous studies suggested that water with a neutral pH value and lower content of mineral substance (TDS) is more conducive to brewing green tea.[7, 12, 13] The tea infusions brewed in water with higher pH and TDS, generally had a darker color and lower overall sensory acceptability. These findings suggested that low mineral brewing water (< 50 ppm) was better for Chinese tea, both from the sensory and health benefit perspectives.[10, 14, 15] Hence, in this study, alkaline water (A) at alkaline pH but lower TDS (56.3 ± 0.6 ppm) was a better choice of brewing water type than the mineral water (M) which was also at alkaline pH but too high in TDS (151.7 ± 0.6 ppm) which will produce a darker color and lower overall sensory acceptability of tea soups. This is due to the catechins in tea leaves, which are among the least stable flavonoids[16-18] and would be expected to be easily vanish to oxidative polymerization by the high pH and TDS of mineral water. The catechin polymers are usually related to the dark yellow/orange/red appearance colors, i.e., theaflavins, thearubigins and theabrownins, and could lead to the yellowing of tea infusion. In the context of the sweetness of tea infusions, it has been reported that excessive Ca^{2+} ions in the brewing water for example, natural mineral water at high TDS of 82.02 ± 0.03 ppm, weakened the umami and sweet tastes, increased the astringency and reduced the overall sensory acceptability of green tea infusions,[14] while the sweetness was intermediate if the brewing water used was a natural spring water with TDS of 49.27 ± 0.08 ppm. In contrast, green tea infusions brewed with ultrafiltered water (2.88 ± 0.04 ppm) and distilled water (0.93 ± 0.01 ppm) were sweeter, had almost no unpleasant taste and had higher overall acceptability. [10] Our tasting survey results from the 17 respondents in the rating of tea soups indicate that for sensory acceptability, the rating scores of 4 and 5 were dominated by alkaline water (A) for both white tea and Pu'er ripe tea due to the moderate amount of TDS and mineral ions available in alkaline water (A) which was able to produce a neutral pH, umami and sweet tastes, lighter gold color, more antioxidants and more aroma tea infusions. On the other hand, for rating scores of 3, it was dominated by mineral water (M) and reverse osmosis water (R) for both white tea and Pu'er tea. In conclusion, with moderate TDS, alkaline water (A) appeared to be the preferred water type for brewing tea soups (Figures 9 and 10). It is noted here that the pH of alkaline water is more basic at 9.8 ± 0.1 due to the stronger basic OH^{-} anion instead of CO_3^{2-} anion in mineral water at 8.1 ± 0.2, which occurred in their TDS (56.3 ± 0.6 and 151.7 ± 0.6 ppm, respectively).

Conclusion

This study described and estimated the correlation between different types of brewing water such as alkaline water (A), mineral water (M), reverse osmosis water (R), and distilled water (D) with a white tea and a Pu'er ripe tea towards the sensory acceptability. From the survey results, it can be concluded that alkaline water (A) seemed to be the favored type for brewing tea infusions. Finally, we hope that the outcomes of this study pave the way for future Tea Art studies by using more types of water combination with other types of fermented and non-fermented tea leaves.

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