Food Chemistry 236 (2017) 142–151

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Effect of the type of brewing water on the chemical composition, sensory quality and antioxidant capacity of Chinese teas

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ARTICLE INFO

Article history:
Received 28 August 2016
Received in revised form 18 November 2016
Accepted 21 November 2016
Available online 22 November 2016

Chemical compounds studied in this article:
(−)-Epigallocatechin gallate (PubChem CID: 65064)
Caffeine (PubChem CID: 2519)
(−)-Epicatechin gallate (PubChem CID: 367141)
(−)-Epigallocatechin (PubChem CID: 72277)
(−)-Epicatechin (PubChem CID: 72276)
(−)-Gallocatechin gallate (PubChem CID: 199472)
(−)-Catechin gallate (PubChem CID: 6419835)
(−)-Gallocatechin (PubChem CID: 9882981)
(+)-Catechin (PubChem CID: 1203)

Keywords:
Brewing water
Chemical components
Sensory quality
Antioxidant capacity

ABSTRACT

The physicochemical characteristics, sensory quality, and antioxidant activity of tea infusions prepared with purified water (PW), mineral water (MW), mountain spring water (MSW), and tap water (TW) from Hangzhou were investigated. The results showed that the taste quality, catechin concentration, and antioxidant capacity of green, oolong, and black tea infusions prepared using MW and TW were significantly lower than those prepared using PW. Extraction of catechins and caffeine was reduced with high-conductivity water, while high pH influenced the stability of catechins. PW and MSW were more suitable for brewing green and oolong teas, while MSW, with low pH and moderate ion concentration, was the most suitable water for brewing black tea. Lowering the pH of mineral water partially improved the taste quality and increased the concentration of catechins in the infusions. These results aid selection of the most appropriate water for brewing Chinese teas.

1. Introduction

Tea is consumed worldwide for its distinctive flavour and health benefits. According to the degree of polyphenol oxidation, tea is classified as unfermented (green tea), partially fermented (oolong tea), and fully fermented (black tea) (Yu, Yeo, Low, & Zhou, 2014). However, the flavour, chemical compound concentration, and antioxidant activity of green, oolong, and black tea infusions have been found to be remarkably influenced by the mineral ion content and pH of the water used for brewing (Mossion, Potin-Gautier, Delerue, Le Hecho, & Behra, 2008; Wang & Helliwell, 2000; Yau & Huang, 2000; Zhou, Chen, & Ni, 2009).

Significant differences have been found in the yields and concentrations of polyphenols, catechins, caffeine, copper, lead, and fluorine in green tea extracts prepared using tap water, activated carbon adsorbed water, deionised water, distilled water, reverse osmosis water, or ultra-pure water (Zhou et al., 2009). Mossion et al. (2008) reported that the higher the mineral concentration in the water, the lower the extraction yields of aluminium, organic carbon, and polyphenols in the infusions. This was due to calcium uptake by the tea leaves, such that calcium in the mineral water could complex with pectins present in cell walls and lead to a decrease in component extraction. Epimerisation occurs more easily in tap water than in purified water; the ion complexity in tap water and

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http://dx.doi.org/10.1016/j.foodchem.2016.11.110
0308-8146/

the pH difference are considered to be the main factors for this phenomenon (Wang & Helliwell, 2000). However, the primary factor for epimerisation of catechins in brewed tea infusions is still unclear.

The sensory quality of tea infusions is also influenced by water sources containing different concentrations of mineral ions (Chakraborty & Baruah, 1971; Yau & Huang, 2000). In our former study, the taste and visual appearance (mainly based on turbidity) were found to be significantly inferior when the Ca^{2+} concentration was over 40 mg/L in the brewing water (Xu et al., 2013). Increasing the Ca^{2+} concentration in water was found to weaken the bitter, umami and sweet tastes, and strengthen the astringent taste of tea infusions prepared from instant green tea (Yin et al., 2014). However, the influence of brewing water having different concentrations of mineral ions and pH on the taste of tea infusions has rarely been reported.

The chemical components of tea leaves include polyphenols (catechins and flavonoids), alkaloids (caffeine, theobromine, and theophylline), amino acids (theanine, glutamic acid, aspartic acid, etc.) and inorganic elements (calcium, manganese, fluorine, chlorine, etc.) (Sharangi, 2009). Among these components, polyphenols are primarily responsible for the health benefits of tea, and catechins are the primary components of polyphenols. Tea catechins have been found to be better antioxidants than vitamins C and E, tocopherol, and carotene (Frei & Higdon, 2003; Sharangi, 2009). In addition, the antioxidant activity of green tea extract was found to be influenced by the brewing water, and green tea extracts prepared using reverse osmosis water were found to have the highest antioxidant activity (Zhou et al., 2009).

The aim of this study was to investigate the effect of brewing water having different concentrations of mineral ions and pH on the chemical composition, sensory quality and antioxidant activity of tea infusions (green, oolong and black teas) containing different concentrations of catechins. Our results can be used to select the most suitable water for tea brewing.

2. Materials and methods

2.1. Chemicals

Caffeine, (−)-epigallocatechin (EGC), (−)-epicatechin (EC), (−)-epicatechin gallate (ECG), (−)-epigallocatechin gallate (EGCG), (+)-catechin (C), (−)-catechin gallate (CG), (−)-gallocatechin (GC), (−)-gallocatechin gallate (GCG) and glutamic acid were purchased from Sigma (Shanghai, China). Dried NaOH was purchased from Shanghai Suke Chemical Co. Ltd. (Shanghai, China). Green, oolong and black teas were obtained from the Tea Research Institute of the Chinese Academy of Agricultural Sciences. Pure water (PW) from Hangzhou Wahaha Group Co., Ltd. (Hangzhou, China), mountain spring water (MSW), Hupao Cool Spring, from Hangzhou Tongsheng Water Co., Ltd (Hangzhou, China), mineral water (MW) from Kunlun Mountains Mineral Water Co., Ltd (Geermu, China) and tap water (TW) were used for the experiments.

2.2. Preparation of tea infusions

According to the Chinese national standards of tea sensory evaluation (Gong et al., 2009), the tea leaves were brewed with a leaf/water ratio of 1:50 (w/w) with boiling water for 5 min. The leaves were removed by filtration and the infusion was quickly cooled to 30 °C in a cooling tank. The cooled infusions were then used for sensory evaluation and analysis of their chemical composition.

2.3. Analysis of pH and conductivity

The pH values were determined using a pH meter (SG2, Mettler-Toledo Instruments (Shanghai) Co., Ltd., Shanghai, China). Buffer solutions at pH 4.01 and 7.01 (Mettler-Toledo) were used to calibrate the pH meter. Conductivities were measured using a conductivity meter (DDB-303, Shanghai Mai Instrument and Meter Co., Ltd., Shanghai, China).

2.4. Analysis of anions and metal cations

The minerals in the waters and tea infusions were determined by Inductively Coupled Plasma Mass Spectrometry (ICP-MS, Thermo Jarrell Ash Corp. America) (Yin, Xu, Yuan, Luo, & Qian, 2009). The analytical conditions were as follows: a charge-injection device detector; low wavelength maximum integration time: 15 s; high wavelength maximum integration time: 5 s; nebuliser pressure: 28 psi; pump speed: 100 r/min; auxiliary gas flow: medium (1 L/min); RF power: 1150 W.

Anions in the water and tea infusions were determined by ion chromatography (Dionex, Thermo Fisher Scientific Inc. Shanghai, China). Anions were analysed after calibration with a four anion standard solution containing 5 mg/L each of F^-, Cl^-, SO_4^{2-} and NO_3^- (Dionex).

2.5. Analysis of catechins, caffeine and amino acids

Catechins and caffeine were analysed by high performance liquid chromatography (HPLC) (Zhang et al., 2016). The tea infusions were filtered through a 0.2 μm Millipore filter before injection (Model Shimadzu LC-20A, Shimadzu (Suzhou) Corporation, Suzhou, China). The HPLC conditions were as follows: injection volume: 10 μL; column: 5 μm Diamonsil™ C18 (4.6 mm × 250 mm); temperature: 35 °C; mobile phase A: acetonitrile/acetic acid/water (6:1:193); mobile phase B: acetonitrile/acetic acid/water (60:1:139); gradient: 100% mobile phase A to 100% mobile phase B by linear gradient during the first 25 min and then 100% mobile phase B for 5 min; flow rate: 1 mL/min; detector: Shimadzu SPD-10A ultraviolet detector (Shimadzu (Suzhou) Corporation) at 280 nm. The HPLC-chromatograms of catechins and caffeine are shown in the Supporting materials.

The concentrations of amino acids in the tea infusions were determined using a spectrophotometer (UV-2550, Shimadzu (Suzhou) Instruments Manufacturing, Co., Ltd. Suzhou, China) by the ninhydrin method (Yin et al., 2009) at 540 nm, using glutamic acid as the standard.

2.6. Colour measurement of tea infusions

The colour of each tea infusion was analysed using a spectrophotometer CM-3500d (Konica Minolta (China) Investment Ltd., Shanghai, China). Since colour changes are difficult to interpret by the most commonly used L^* (lightness) a^* (redness) b^* (yellowness) International Commission on Illumination (CIE) coordinates, the L^*C^* (chroma) $H°$ (hue angle) system, recommended by the CIE as an optimised version of the CIE $L^*a^*b^*$ method in 1976 (Sui, Bary, & Zhou, 2016), was used in this study. The $L^*C^*H°$ coordinates were calculated from the $L*a*b*$ values using the following equations: $C^* = \sqrt{(a^*2 + b^*2)}$ and $H° = \tan^{-1} b^*/a^*$.

2.7. Sensory evaluation of green tea infusions

The infusions were scored by a trained team of 9 panellists (5 men and 4 women, 25–48 years old) from the Tea Research