



Contents lists available at SciVerse ScienceDirect

Food Research International

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

Objective evaluation methods for the bitter and astringent taste intensities of black and oolong teas by a taste sensor

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ARTICLE INFO

Article history:

Received 26 June 2012

Accepted 8 January 2013

Available online xxxx

Keywords:

Black tea

Oolong tea

Bitter taste

Astringent taste

Taste sensor

ABSTRACT

In order to objectively indicate the bitter taste intensities of black and oolong teas on the basis of a permanent standard point, a taste sensor method was developed that calibrated the sensor outputs with standard solutions prepared with only pure chemicals. Ethyl gallate (EG) was used as the standard substance. The sensor outputs were converted into the bitter taste intensities using two EG solutions at different concentrations. The astringent taste intensities of these teas were evaluated by the similar method. In this case, (–)-epigallocatechin-3-*O*-gallate (EGCg) was used as the standard substance. These evaluation results by the taste sensor system showed a similar tendency as those by human gustatory sense. Relative standard deviations of the sensor results revealed that these evaluation methods possessed enough practical precisions. Two-dimensional mapping analysis of the bitter and astringent taste intensities showed that, as a whole, the taste intensities of the Indian and Sri Lankan black tea samples had a tendency to be stronger than those of the Chinese oolong tea samples under the sample preparation conditions in this study.

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1. Introduction

Taste is one of the most important factors for deciding food quality. Although it is typically evaluated by a human gustatory sense, the sensory test can be potentially affected by individual preference and physical and mental conditions. Recently, taste sensor systems have received attention as a way to resolve these problems and these sensing technologies have been applied to evaluations of various food tastes (Chen, Zhao, & Vittayapadung, 2008; Chikuni et al., 2010; Ciosek & Wróblewski, 2007; Citterio & Suzuki, 2008; Fujita et al., 2010; Habara & Toko, 2006; Matsuo et al., 2012; Mizota et al., 2008; Narukawa, Kimata, Noga, & Watanabe, 2010; Riul, Dantas, Miyazaki, & Oliveira, 2010; Sasaki et al., 2005; Toko, 2000, Chap. 6; Tran et al., 2005; Vlasov, Legin, & Rudnitskaya, 2002; Wu, Yeh, Yu, & Chen, 2008). We previously reported evaluation methods for the astringent and umami taste intensities¹ of Japanese green tea and the astringent taste intensity of black tea by a commercially available taste sensor system that employed sensor probes in which information about taste intensities was detected as a membrane potential

change (Hayashi, Chen, Ikezaki, & Ujihara, 2008; Hayashi et al., 2006; Hayashi et al., 2007). Each sensor probe in the system was designed to preferentially respond to substances with target tastes (Habara & Toko, 2006; Kobayashi et al., 2010).

In quantifying food taste intensities using the taste sensor, calibrations of the sensor outputs are one of the most important considerations to ensure the precision of the sensing results. In usual sensor experiments, the sensor outputs of the samples are often indicated on the basis of that of a reference food sample. For example, in the case of green tea, commercially available green tea beverages have been applied for setting a standard point. However, in the case of such references, a constant property, which is an essential factor for a standard of quantification, is not ensured due to quality deterioration and interlot variation. In addition, the availability of reference food samples is uncertain because it depends on regions or periods in which the reference foods can be obtained. Therefore, in order to compare the taste intensities of samples without such concerns, it is extremely significant to set permanent standard points for the calibrations. In our previous study, for this purpose, standard solutions prepared with pure chemicals (standard substances) were used instead of food reference samples. This approach can eliminate concerns about the availability and reproducibility of standard samples. Moreover, the sensor outputs were calibrated with two standard solutions. When taste intensities are compared among same kinds of foods, the two-point calibration method is effective because the small difference within the comparatively narrow sensor output range need to be discriminated.

Abbreviations: EG, ethyl gallate; EGCg, (–)-epigallocatechin-3-*O*-gallate; EIT, estimated intensity of taste; EIT_{bite}, estimated intensity of bitter taste; EIT_{ast}, estimated intensity of astringent taste; RSD, relative standard deviation.

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¹ Although astringency is not a basic taste, it has been interpreted as a taste in the general meaning, particularly in evaluating tea in Asian area. Therefore, in this article, astringency is described as an astringent taste.

Bitter taste is an important factor characterizing tea tastes. A lot of bitter evaluation methods have been reported (Chen, Wu, Zhao, Xu, & Hu, 2012). However, no evaluation of the bitter taste intensity of tea in accordance with the above-mentioned methodology has been reported, although a bitter taste sensor of the sensing system has been used for evaluating the changes in the taste intensities of tea due to oxidation degrees (Uchiyama et al., 2011) and the bitter taste intensities of beers (Habara & Toko, 2006). In this study, by targeting black and oolong teas, we undertook the challenge of adding a new method for measuring the bitter taste intensities to a series of the taste sensor methods for evaluating the taste intensities of teas using standard substances. Although these teas are both produced with enzymatic oxidation processes, black tea is more oxidized than oolong tea. Difference in chemical composition in tea leaves with the degree of the enzymatic oxidation characterizes each tea type (Chaturvedula & Prakash, 2011). In this paper, the calibration method of the bitter taste sensor outputs, the relationship between the sensor results and human gustatory sense, and the precision of the sensor results are described. In addition, in order to evaluate the astringent taste intensity of oolong tea, the extension of the existing methods for the astringent taste of black tea is discussed.

2. Materials and methods

2.1. Materials

Tea leaf samples were obtained from commercial suppliers. EG was purchased from Tokyo Chemical Industry Co., Ltd. (Tokyo, Japan, purity > 98.0%). (–)-Epigallocatechin-3-*O*-gallate (EGCg) was obtained by recrystallizing TEAVIGO™ (DSM Nutritional Products, Heerlen, Netherlands) from hot pure water. All other chemicals were commercially available special grade reagents. Tea infusions and aqueous solutions were prepared with pure water obtained by a reverse osmosis water purifier.

2.2. Methods

2.2.1. Preparation of tea infusions for taste sensor measurement

Tea leaves (2.00 g) were added to a plastic filter cup in a glass pot (type GAV-2, Selec, Gifu, Japan). Boiling pure water (200 mL) was poured into the pot and the mixture was allowed to stand for 5 min at ambient temperature (25 °C). The plastic filter cup was removed and the residual infusion among the tea leaves was strained from the filter cup into the glass pot without shaking. The infusion was cooled to ambient temperature in an ice-water bath, and then filtered through filter paper (Advantec No. 2, Toyo Roshi, Tokyo, Japan). The filtrate was used for the taste sensor measurement.

2.2.2. Measurements of the bitter taste intensities by the taste sensor system

The electrical potential corresponding to the bitter taste intensity was measured by the SA402B or TS-5000Z taste sensor system (Intelligent Sensor Technology, Inc., Kanagawa, Japan), fitted with a sensor probe for bitter taste (SB2C00) and a reference probe. The bitter taste sensor probe consisted of a polymer membrane, an Ag/AgCl electrode, and an internal cavity filled with 3.3 M KCl aqueous (aq.) solution saturated with AgCl. The polymer membrane was composed of tetradodecylammonium bromide, 2-nitrophenyl octyl ether, and poly(vinyl chloride). The reference probe consisted of a liquid junction made with ceramics, an Ag/AgCl electrode, and an internal cavity filled with 3.3 M KCl aq. solution saturated with AgCl.

The sensor measurement was automatically carried out at 25 °C. The taste sensor probe and the reference probe were dipped into sample solutions or standard substance solutions for 30 s to detect the membrane potential change. The bitter taste intensity of the sample solution was defined as the difference (ΔE_{bit}) between the membrane

potential change in the sample solution and in the reference solution (2.00 mM EG aq. solution including 5.00 mM KCl).² The ΔE_{bit} value of each sample was obtained by the average of three measurements. The measurement order was 2.00 mM EG aq. solution, 0.500 mM EG aq. solution, and the sample solutions.

2.2.3. Measurements of the astringent taste intensities by the taste sensor system

The electrical potential corresponding to the astringent taste intensity was measured by the SA402B or TS-5000Z taste sensor system, fitted with a sensor probe for astringent taste (SB2AE1) and the reference probe. The astringent taste sensor probe consisted of a polymer membrane, an Ag/AgCl electrode, and an internal cavity filled with 3.3 M KCl aq. solution saturated with AgCl. The polymer membrane was composed of tetradodecylammonium bromide, dioctylphenyl phosphonate, and poly(vinyl chloride).

The sensor measurement was automatically carried out at 25 °C. After the taste sensor probes and the reference probe were dipped into sample solutions or standard substance solutions for 30 s, these probes were washed twice for 3 s in 30 mM KCl and 0.30 mM tartaric acid aq. solutions. Then, the membrane potential of the astringent sensor was detected in 30 mM KCl and 0.30 mM tartaric acid aq. solution. This operation was performed for detecting the membrane potential change generated by astringent taste substances adsorbed on the polymer membrane of the sensor probe.³ The astringent taste intensity of the sample solution was defined as the difference (ΔE_{ast}) between the membrane potential changes caused by the sample solution and by the reference solution (0.650 mM EGCg aq. solution including 5.00 mM KCl).⁴ The ΔE_{ast} value of each sample was obtained by the average of three measurements. The measurement order was 0.650 mM EGCg aq. solution, 0.260 mM EGCg aq. solution, and the sample solutions.

2.2.4. Sensory test

In order to evaluate the bitter or astringent taste intensities of tea samples by the human gustatory sense, for each taste, the eight tea samples were selected from the samples used in the taste sensor experiments. Tea leaves (5.00 g) were added to a plastic filter cup in a glass pot (type GV-3, Selec, Gifu, Japan). Boiling pure water (500 mL) was poured into the pot. The mixture was allowed to stand for 5 min at ambient temperature (25 °C). The plastic filter cup was removed and the residual infusion among the tea leaves was strained from the filter cup into the glass pot without shaking. The infusions were cooled to ambient temperature in an ice-water bath.

Each sensory test was performed with twelve panelists. Although they were not specially trained for the sensory test in this study, people who had often participated in sensory tests for evaluating the tastes of many different kinds of foods or beverages were used as panelists. The panelist was given 35 mL of each tea sample solution. About 5 mL of the sample solution was taken into mouth and ejected after tasting. Before the next examination, their mouths were rinsed out thoroughly with pure water. The samples were ranked according to the relative intensity of bitter or astringent taste. In the test for the astringent taste intensity, each sample was kept in the panelist's

² Potassium chloride was added as an auxiliary electrolyte to the 2.00 mM EG reference solution for obtaining steady sensor outputs. However, 5.00 mM KCl had little influence on the sensor output in the reference solution: the sensitivity of the bitterness sensor for 2.00 mM EG was about 30 times more than that for 5.00 mM KCl.

³ To obtain only the information of the astringent taste substances adsorbed on the sensor membrane, the sensor outputs caused by 30 mM KCl and 0.30 mM tartaric acid were subtracted with the sensor output premeasured in 30 mM KCl and 0.30 mM tartaric acid solution.

⁴ Potassium chloride was added as an auxiliary electrolyte to the 0.650 mM EGCg reference solution for obtaining steady sensor outputs. However, 5.00 mM KCl had no influence on the sensor output for the reference solution.

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