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Note

Evaluation of the Astringency of Black Tea by a Taste Sensor System: Scope and Limitation

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Grading the astringency of black tea by a taste sensor system was studied. The black tea samples manufactured in India and Sri Lanka were classified into ten steps on the basis of two standard solutions (0.65 mM and 0.26 mM EGCg aqueous solutions). An organoleptic test demonstrated that the sensor output was correlative to the human gustatory sense.

Key words: evaluation of astringency; taste sensor; black tea

Our recent endeavors toward an evaluation of the taste of a green tea infusion by the use of a taste sensor system (Intelligent Sensor Technology model SA402B) have established a practical and universal method for assessing its astringency.[1)] The essential points for high accuracy of the analysis were to use an (−)-epigallocatechin-3-*O*-gallate (EGCg) aqueous solution as a standard and to introduce the EIT_{ast} scale,* one unit of which is defined as the amount of sensor output corresponding to a difference of 1.2 times the concentration of the standard substance (in this case, EGCg). Furthermore, it was revealed that the EIT_{ast} value was correlated with the contents of the major catechins. We have been interested in whether this analytical method would be applicable to assessing the astringency of black tea, and not only that of green tea. It is generally presumed that the astringency of a tea infusion is induced by the polyphenolic compounds.[2–5)] However, the composition of the polyphenols in fermented black tea is different from that in non-fermented green tea in that it includes teaflavins and tearubigins produced in the process of tea fermentation by the oxidation of flavan-3-ols.[3,5–11)] Therefore, we recognized the necessity to study afresh the analytical method. In this Note, we report the scope and limitation of the taste sensor method for evaluating black tea astringency.

The range of sensor output responding to the astringency of a black tea infusion was first investigated. Both full-type and broken-type tea leaves were chosen as test samples from major sources in India, Sri Lanka, and China. In addition, many black teas manufactured in Japan also were used for a comparison with the major black teas. Although African black tea is one of the major teas, it was not used in the present study, because it is difficult for African tea manufactured by the CTC process to be compared with leaf-type tea owing to a difference in the infusing rate.** The sample preparation and analytical methods were carried out in the same as that manner used previously for the green tea infusion. The taste sensor analysis of the 98 black tea infusions revealed that the $\Delta E_{ast}^{sam\ (CPA)}$ value of the black tea have a somewhat wider range than that of green tea toward the less astringent field (Fig. 1): the former range was $-50 \sim -7$ mV on the basis of a 5 mM KCl aqueous solution, the latter range was $-50 \sim -20$ mV. The $\Delta E_{ast}^{sam\ (CPA)}$ value decreases with increasing astringency. Here, $\Delta E_{ast}^{sam\ (CPA)} = \delta E_{ast}^{sam\ (CPA)} - \delta E_{ast}^{std\ (CPA)}$, where $\delta E_{ast}^{sam\ (CPA)}$ and $\delta E_{ast}^{std\ (CPA)}$ are the electrical potential differences of the sample and the standard solutions, respectively.[1),***]

In order to evaluate the sensor output as a practical value representing taste intensity, the output must be converted to the EIT_{ast} value. In the case of green tea, 0.65 mM and 0.26 mM EGCg aqueous solutions, which are in a linear relationship on the graph in Fig. 1, were used as the two standard solutions for the conversion.[1)] As described in the previous paper, EGCg is applicable

* "*EIT*" and "*ast*" are abbreviations for "estimated intensity of taste" and "astringency" respectively.
** CTC is an abbreviation for crush, tear, and curl. CTC-type tea infuses considerably more rapidly than leaf-type tea.
*** *CPA* is an abbreviation for change of membrane potential caused by adsorption.

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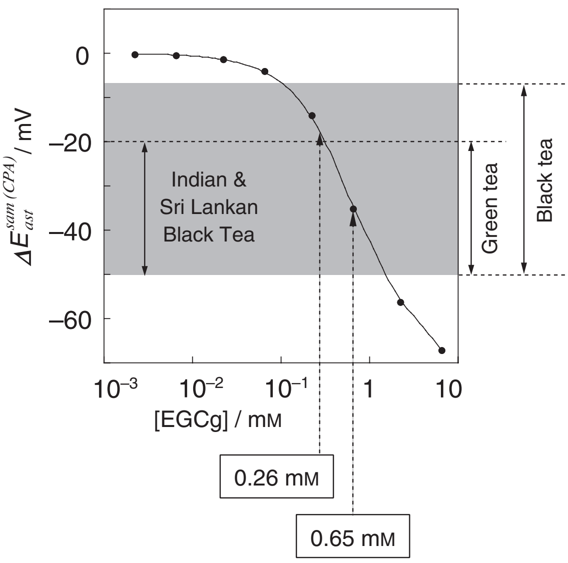

Fig. 1. Relationship between the $\Delta E_{ast}^{sam\,(CPA)}$ Value and the Concentration of EGCg, and the $\Delta E_{ast}^{sam\,(CPA)}$ Range for Black Tea.

as a standard substance for tea from the points of both its low price and chemical behavior. However, this calculating method is not applicable to every black tea sample, because the samples with $\Delta E_{ast}^{sam\,(CPA)} > -15$ mV existed in black tea. As shown in Fig. 1, although the relationship between the concentration of EGCg and the corresponding $\Delta E_{ast}^{sam\,(CPA)}$ value is linear in the $-50 \sim -15$ mV range, the slope remarkably diminishes in the range of more than -15 mV. However, the relatively non-astringent samples giving $\Delta E_{ast}^{sam\,(CPA)} > -20$ mV were interestingly limited to the Chinese and Japanese black teas which together have a unique flavor in comparison with Indian or Sri Lankan black teas. On the other hand, the infusions prepared from the Indian and Sri Lankan tea leaves showed $\Delta E_{ast}^{sam\,(CPA)}$ values between -50 mV and -20 mV, where the graph in Fig. 1 gives linearity. Therefore, we conclude that the astringency of orthodox black tea manufactured in India and Sri Lanka can be successfully evaluated by using a 0.65 mM and 0.26 mM EGCg aqueous solution including 5 mM KCl as a standard, like the green tea infusion. However, it might not be easy to accurately estimate the astringency of every Chinese or Japanese black tea under the same conditions, because samples of $\Delta E_{ast}^{sam\,(CPA)} > -15$ mV exist in these black teas.

The EIT_{ast} values of the 59 black tea samples including Indian, Sri Lankan, Chinese, and Japanese black tea were determined from 0.65 mM and 0.26 mM EGCg aqueous solutions. The EIT_{ast} values ranged from about -8 to about $+4$ (Fig. 2). The EIT_{ast} value increases with increasing astringency. The bias of the EIT_{ast} values toward non-astringent range is due to the many extremely non-astringent samples prepared from the Chinese and Japanese tea leaves, most of which showed $-8 < EIT_{ast} < -4$. In this range, the EIT_{ast} value on the basis of the foregoing standard solutions cannot assure accuracy, because the linearity of the graph in Fig. 1 is lost in the range of $EIT_{ast} <$ about -6. The sample solutions prepared from the Indian and Sri Lankan tea leaves gave EIT_{ast} values between -4 and $+4$. Therefore, the present analytical conditions are applicable to evaluating these black teas. It is proposed that the astringency of the Indian and Sri Lankan black tea be classified into ten grades by the taste sensor system: in non-astringent order, level 1 ($EIT_{ast} < -4$), level 2 ($-4 \le EIT_{ast} < -3$), level 3 ($-3 \le EIT_{ast} < -2$), level 4 ($-2 \le EIT_{ast} < -1$), level 5 ($-1 \le EIT_{ast} < 0$), level 6 ($0 \le EIT_{ast} < +1$), level 7 ($+1 \le EIT_{ast} < +2$), level 8 ($+2 \le EIT_{ast} < +3$), level 9 ($+3 \le EIT_{ast} < +4$), and level 10 ($+4 \le EIT_{ast}$).

In order to compare the sensor output with human gustatory sense, twelve of the samples used in Fig. 2 were graded organoleptically according to their relative astringency. The infusion prepared from Chinese and Japanese tea leaves which gave $EIT_{ast} < -6$ was included in these twelve samples, because we needed

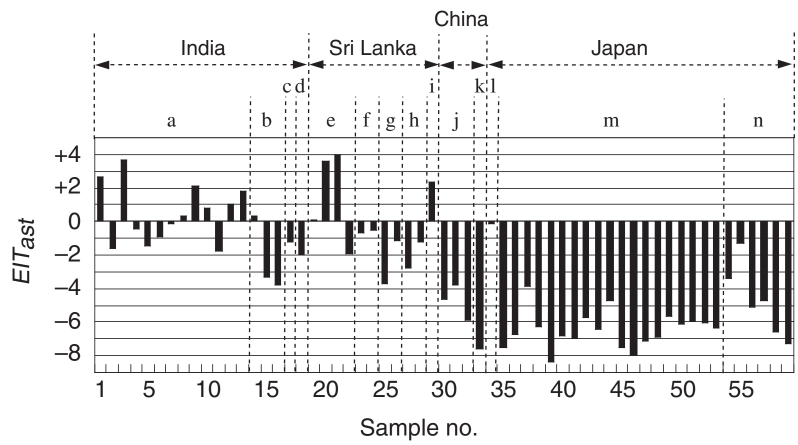

Fig. 2. EIT_{ast} Values for the Black Tea Infusions.

a, Darjeeling; b, Assam; c, Sikkim; d, Nilgiri; e, Uva; f, Dimbra; g, Kandy; h, Ruhuna; i, Nuwara Eliya; j, Keemun; k, Lapsang Souchong; l, unknown (Benihomare); m, Shizuoka; n, Mie.

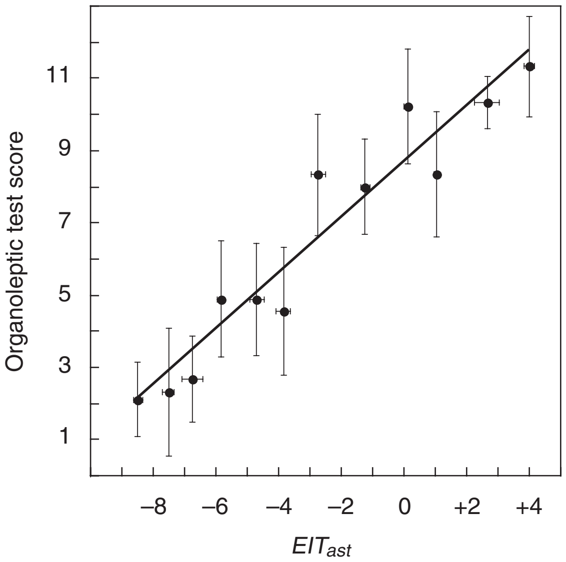

Fig. 3. Correlation between the EIT_{ast} Value and the Human Gustatory Sense.
Error bars indicate the standard deviation.

to know how much the sensor output was correlated with human gustatory sense even in the case including the range where the accurate EIT_{ast} value is not ensured. The sample preparation was carried out in the same manner as that used previously for the green tea infusion.[1] Organoleptic tests were performed with eight healthy (trained and expert) panelists. Each sample was kept in the panelist's mouth for 5 s, and then was graded into twelve steps according to its relative astringency. Figure 3 shows a plot of the EIT_{ast} values against the scores in the organoleptic test, where a higher score represents greater astringency. These results reveal that the EIT_{ast} value was correlated with the human gustatory sense (linear correlation coefficient = 0.95), and demonstrate that the EIT_{ast} value reflected the human gustatory sense in the astringency of black tea as well as that in green tea, even if the samples with $EIT_{ast} < -6$ are included.

In conclusion, the taste sensor system could classify the astringency of Indian and Sri Lankan black tea into ten grades by using the analytical conditions developed for green tea. Although the EIT_{ast} values for Chinese (and Japanese) black tea calculated by using the present standard solutions were not theoretically accurate in the case of $EIT_{ast} < -6$, their values might be correlative to the human gustatory sense to a certain extent from the organoleptic test. However, if we hope to estimate more accurately the astringency of Chinese or Japanese black tea, the use of other standard solutions is needed, instead of the combination of the 0.65 mM and 0.26 mM EGCg aqueous solutions.

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References

1) Hayashi, N., Chen, R., Ikezaki, H., Yamaguchi, S., Maruyama, D., Yamaguchi, Y., Ujihara, T., and Kohata, K., Techniques for universal evaluation of astringency of green tea infusion by the use of a taste sensor system. *Biosci. Biotechnol. Biochem.*, **70**, 626–631 (2006).
2) Nakagawa, M., Relation of catechins with the qualities of green and black tea. *Bull. Tea Res. Stat. Minis. Agric. Forest.* (in Japanese: the summary is written in English), **6**, 65–166 (1970).
3) Wood, D. J., and Roberts, E. A. H., The chemical basis of quality in tea. III. Correlations of analytical results with tea tasters' reports and valuations. *J. Sci. Food Agric.*, **15**, 19–25 (1964).
4) Millin, D. J., Crispin, D. J., and Swaine, D., Non-volatile components of black tea and their contribution to the character of the beverage. *J. Agric. Food Chem.*, **17**, 717–722 (1969).
5) Robertson, A., and Bendall, D. S., Production and HPLC analysis of black tea theaflavins and thearubigins during *in vitro* oxidation. *Phytochemistry*, **22**, 883–887 (1983).
6) Roberts, E. A. H., The phenolic substances of manufactured tea. II. Their origin as enzymic oxidation products in fermentation. *J. Sci. Food Agric.*, **9**, 212–216 (1958).
7) Nakagawa, M., and Torii, H., Syudies on the flavanols in tea part IV. Enzymic oxidation of flavanols. *Agric. Biol. Chem.*, **29**, 278–284 (1965).
8) Berkowitz, J. E., Coggon, P., and Sanderson, G. W., Formation of epitheaflavic acid and its transformation to thearubigins during tea fermentation. *Phytochemistry*, **10**, 2271–2278 (1971).
9) Hilton, P. J., *In vitro* oxidation of flavanols from tea leaf. *Phytochemistry*, **11**, 1243–1248 (1972).
10) Sanderson, G. W., Bekowitz, J. E., Co, H., and Graham, H. N., Biochemistry of tea fermentation: products of the oxidation of tea flavanols in a model tea fermentation system. *J. Food Sci.*, **37**, 399–404 (1972).
11) Hashimoto, F., Nonaka, G., and Nishioka, I., Tannins and related compounds. CXIV. Structures of novel fermentation products, theogallinin, teaflavonin and desgalloyl teaflavonin from black tea, and changes of tea leaf polyphenols during fermentation. *Chem. Pharm. Bull.*, **40**, 1383–1389 (1992).