2.3 Hyperspectral imaging system

The hyperspectral imaging system (Fig. 1) was mainly composed of an imaging spectrograph (ImSpector, V10E, Finland), two 150 W halogen lamps (DC-950A, Dolan-Jenner, Co., USA), a precision conveying device set (Zhuoli Hanguang, SC300-1 A, Beijing), a 14-bit thermoelectrically cooled electron multiplying charge-coupled device (EMCCD), a camera (Andor Luca EMCCD DL-604M, Andor Technology plc., N. Ireland), and a computer. The spectral resolution was 2.8 nm.

The collected hyperspectral images need to be calibrated using following formula:

$$R = \frac{R_{raw} - R_{dark}}{R_{white} - R_{dark}}$$

Where R_{raw} and R denote the raw hyperspectral images and calibrated hyperspectral images, respectively. The R_{white} and R_{dark} represents the white reference image and dark current image, respectively.

2.4.3. Image acquisition and feature extraction

The 12 color image features: red component mean value(R), green component mean value(G), blue component mean value(B), hue mean value(H), saturation mean value(S), visible light mean value(V), brightness component mean value(L*), a component mean value(a*), b component mean value(b*), ultragreen transform (2G-R-B), ratio of red component mean value to green component mean value (R/G), color angle (hab*). The 6 texture features: average gray value (m), standard deviation (δ), smoothness (r), third moment (μ), consistency (U) and entropy (e).

2.4.4. Data fusion and dimension reduction

For the low-level fusion strategy, all the information from different data source is directly concatenated into a new matrix, which was used for the establishment of prediction model. The middle-level fusion is also known as feature level fusion, which means the effective features of raw data are extracted to form a new matrix and establish the prediction model. In contrast to the low- and middle-level fusion strategy, the high-level fusion strategy establishes the prediction model based on the decision information of each data source.

2.4.5. Regression models

To evaluate the performance of established taste quality regression model of black tea, some effective parameters, i.e., correlation coefficients of the calibration set (R_c), prediction set (R_p), the root mean square error of calibration set (RMSEC), the prediction set (RMSEP) and RPD, were proposed. A robust and accurate regression model is characterized by high values of R_c, R_p, and RPD, indicating strong correlation and prediction capability, and low values of RMSEC and RMSEP, reflecting minimal errors in model calibration and prediction, respectively.

The statistical graphs were drawn based on Origin 2021b (OriginLab Corp. Massachusetts, USA). Other data analyses were performed in Matlab R2017b software (The Math Work, Inc., Natick, MA, USA).

Table S1. The obtained taste scores of black tea at different fermentation times by 5 professional tea tasters

Time (h)	Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Average
0	88	87	88	89	88	88
1	89	88	90	90	88	89
2	91	90	92	90	92	91
3	92	91	93	91	93	92
4	91	90	92	90	92	91
5	90	89	91	89	91	90
6	89	88	90	88	90	89
7	88	87	88	87	90	88

Table S2. Comparison with previous studies

Technology	Objective	Results	Reference
FT-NIR	Evaluating the taste quality and taste-related components content of black tea	R_p of 0.8462, 0.9089, 0.7126, 0.8866,0.9428,0.7199,0.7194,0.8074 and 0.7726 for taste score, water extracts, total polyphenols, free amino acids, caffeine, total catechins, theaflavin-3-gallate, theaflavin-30-gallate and theaflavins, respectively.	Chen et al., J Food Sci. Technol., 2018
E-tongue	Evaluating the quality of black tea	1.Converting the obtained characteristic potential signals into relative characteristic taste values. 2.The LS-SVM model using the five taste features could accurately distinguish the tea grade and the correct discriminant rate was 99.14%.	Ren et al., Microchem J., 2021
NIR	Evaluating taste-related attributes of black tea	R_p of 0.9437, 0.9119, 0.9509 and 0.9387 for bitterness, astringency, caffeine and EGCG, respectively.	Wang et al., J. Food Eng., 2021
CVS	Sensory quality evaluation for appearance of needle-shaped green tea	1.The Ada-ELM model displayed the best performance. 2.R_p of 0.892 for the sensory scores.	Dong et al., J. Zhejiang Univ Sci. B., 2017
CVS	Tea pigments and sensory quality evaluation during black tea fermentation	1.The RF model displayed the best performance for TFs, TRs, TBs and sensory scores. 2.Rp of 0.891, 0.890, 0.944 and 0.948 for TFs, TRs, TBs and sensory scores, respectively.	Dong et al., Sci. Rep., 2018
NIRS & E-Tongue	Rapid characterization of black tea taste quality	The ACO-SVM model could accurately distinguish the tea grade and had the highest classification accuracy with a discriminant rate of 93.56%.	Ren et al., Biosensors., 2023
HIS (spectra & image)	Evaluating the taste quality during black tea fermentation	The established PLSR model using fusion-SPA strategy exhibited the best prediction performance. The values of Rc, Rp and RPD were 0.986, 0.978 and 4.118, respectively.	Our study

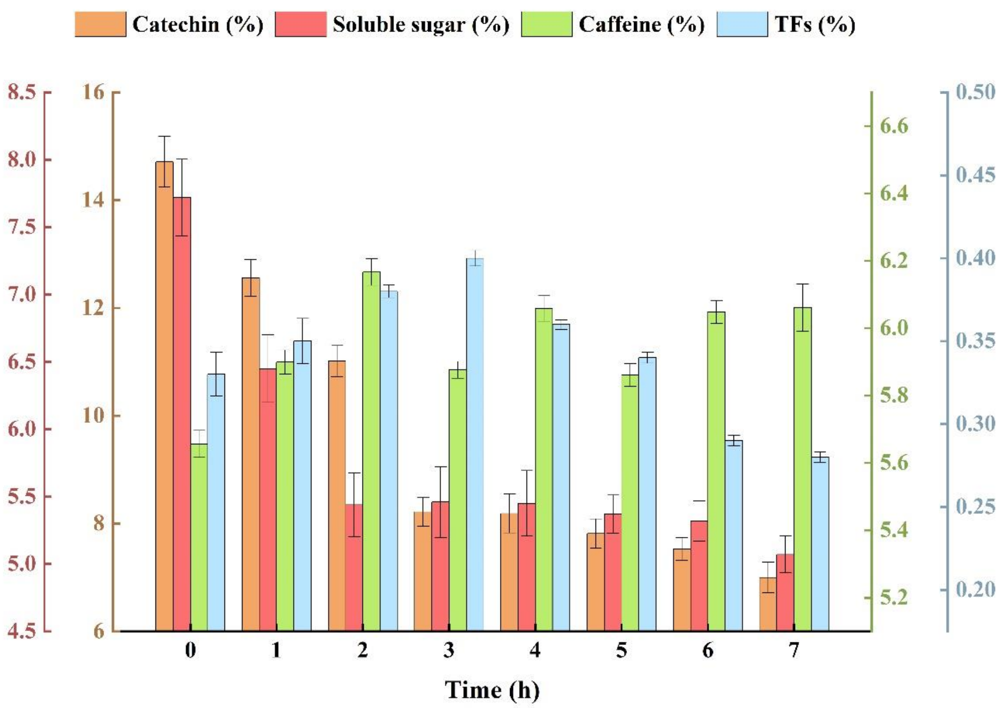

Figure S1. Effects of different fermentation times on the content of catechin, soluble sugar, caffeine and theaflavins (TFs) in black tea.