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Development of a model for quality evaluation of litchi fruit

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ABSTRACT

Sensory quality of litchi fruit is closely related to the appearance, flavor and nutritional quality. Principle component analysis (PCA) and multi-linear regression analysis (MLR) were performed to select the crucial quality factors in determining litchi sensory quality, and then a mathematical model was established to evaluate the litchi quality. Sensory evaluation value was conducted by a trained panel while sixteen instrumental quality parameters were used, including color (L^*, a^* and b^*), single fruit weight (SFW), total soluble solids (TSS), pH, crude protein (CP), vitamin C (Vc), titratable acid (TA), glucose, fructose, sucrose, malic acid (MA), tartaric, edible rate (ER), and juice yield (JY). The PCA result demonstrated that six principle components exhibited high relationship with sweet and sour degrees, color, ER, TSS, Vc, CA and JY, which accounted for 82.359% of the original variables, and MLR results indicated that the crucial quality parameters were SFW, TA, a^*, and ER. The predicted model was established in which validity $Q^2_{LOO} = 0.603 > 0.5$ in leave-one-out cross validation. Cluster analysis was used to select the cultivars suitable for eating quality which can provided a guide for litchi production and breeding.

1. Introduction

Litchi (*Litchi chinensis* Sonn.) is a subtropical to tropical tree in the Sapindaceae family, originates from South East Asian (Nakasone and Paull, 1998) and has been widely planted in China, India, subtropical Asia, Hawaii, Israel, Mexico, Australia, and South-Africa (Jiang et al., 2001). Ouyang et al. (2007) reported that the accession number of Chinese litchi germplasm were more than 300 by estimation and collection, classification. In China, litchi is cultivated in many provinces, including Guangdong, Guangxi, Fujian, Hainan, Yunnan and Sichuan provinces (Wu et al., 2007). According to the statistics, Zhu et al. (2005) reported that Guangxi Province has the most number of cultivars (99), followed by Hainan (70), Guangdong (57) and Fujian (40). However, only limited number of litchi cultivars has been produced and marketed commercially (Wang and Chen, 2008). A vast number of litchi cultivars need to be exploited and commercialized at the aim of promoting the production of these litchi cultivars. Thus, a standard or criterion to evaluate the quality of litchi fruit is urgent to be established to select excellent litchi cultivars.

The quality of food products can be determined by their sensory attributes, nutritional compositions and physical properties. Among all of these factors, the sensory attributes exhibit the crucial factor influencing the market success. Evaluation of product quality requires the collection of a large number of data and statistical analysis methods to reduce variables and give presentation in a clear and graphical way (Naes et al., 1996). Principle component analysis (PCA) approach has been used to reduce numerous original variables into linear combinations of source data, so that the principle components are used to explain the majority of total variability of original magnitudes (Vainionpaa et al., 2004). It has been used to select the most useful parameters for quality control analysis of apple, jujube, table grape, orange, longan and apricot (Fan et al., 2009, 2012; Li et al., 2010; Yang et al., 2011; Zhuo and Chen, 2011; Bai et al., 2012). As for litchi, studies have been conducted to evaluate the fruit quality by color, size, hardness, total soluble solids (TSS), titratable acid (TA), single fruit weight (SFW) and weight. To make a comprehensive evaluation, sixteen quality parameters were analyzed in this investigation, including appearance, flavor and nutritional qualities. PCA was used to reduce the sixteen variables into few ones to explain the comprehensive qualities of litchi fruit. Furthermore, MLR is a method to analyze the correlation between one induced variable and multi-independent variables to select the crucial independent variable in influencing the induced variable by stepwise regression. Thus, MLR was used

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to select the crucial quality parameters in determination of the sensory evaluation value (SEV) of litchi fruit. In this study, a mathematical model with leave-one-out validation was established to evaluate comprehensive fruit quality while the cluster analysis was used to select the cultivars suitable for eating quality, to provide a guide for litchi production and breeding.

2. Materials and methods

2.1. Source and handling of Litchi fruit

Litchi fruits were obtained from Guangxi, Fujian and Yunnan Provinces. Mature litchi fruit were randomly harvested in 2011 and transported to the laboratory within 24 h after picking by airplane. To maintain the quality, fruit lots of 10 kg were enclosed with about 8 kg of ice which was covered with plastic bags to avoid direct contact with the fruit. The litchi cultivars engaged in this study included 'Sanyuehong', 'Feizixiao', 'Baitangying', 'Dazao', 'Jiaoli', 'Heli', 'Jizui', 'Sanguihong', 'Mili', and 'Baitangli' from Guangxi province, 'Guiwei', 'Shuangjianyuhebao', 'Chenzi', 'Yuanhong', 'Hushanwanli', 'Nuomici', 'Jidi', 'Guangming', 'Huaizhi', 'Xiafanzhi', 'Midingxiang', and 'Jinzhong' from Fujian province and 'Mangshi', 'Dahongpao', 'Feizixiao', 'Nuomici', 'Baila1', 'Baila2', and 'Daheiye' from Yunnan province. The time of picking were shown in Table 1. The parameters analyzed by instruments were skin color (expressed with L^*, a^* and b^*), single fruit weight (SFW), total soluble solid (TSS), pH, crude protein (CP), vitamin C (Vc), titratable acid (TA), glucose, fructose, sucrose, malic acid (MA), tartaric, edible rate (ER), and juice yield (JY). The immediately analyzed attributes included skin color, SFW, TSS, pH, CP, Vc, TA, JY and ER, while the other ones were measured with the samples after storage at −80 °C. Analyses were conducted for three times and the average was recorded.

2.2. Sensory evaluation

A taste panel comprised of nine adult experienced volunteers (20–60 years old) in sensory evaluation. Panelists were trained before the test to maintain the consistency and uniformity with the sensory evaluation principles. Tasting was performed in individual taste panel booths in the sensory laboratory. Each sample was tasted twice by each panelist and sets of samples were distributed at random without the names of the samples but only their non-zero digit random numbers assigned instead (Sinesio and Moneta, 1997). Water was supplied to the panelists between two samples for rinsing the mouth during the tasting. Intensity scores were recorded using a system that provided a score range of 0–100. Six descriptors were provided to describe the quantitative profiles, including peel color, pulp color, pulp flavor, juice and aroma (Shen et al., 2011), during which the peel color was judged by red degree while evaluation of aroma was separately accomplished in different rooms. These attributes and their scale anchors were given in Table 2.

2.3. Instrumental analysis

2.3.1. Color analysis

Ten fruits from each litchi cultivar were randomly chosen for the analysis of each attribute. Each analysis was repeated three times. The skin color of litchi fruit samples was measured by a chroma meter (CR-400, Konica Minolta Co., Ltd., Japan) in Commission Internationale I'Eclairage (CIE) chromaticity coordinates. L^*, a^* and b^* represent black to white (0–100), green to red (−ve* to +ve) and from blue to yellow (−ve* to +ve) color, respectively. The readings of L^*, a^* and b^* were taken twice on the opposite surfaces of each fruit, and then the mean values of L^*, a^* and b^* of ten fruits were averaged.

2.3.2. Physical and chemical analysis

The mass of each fruit was measured by an analytical balance, and the average of ten fruits was calculated as the single fruit weight (SFW). The total soluble solids (TSS) of the aril were measured using a pocket refractometer PAL-1 (Atago, Japan) which gave values expressed in Brix (°Bx). The value of pH was measured by the pH meter using the pure juice extracted from aril. The titratable acid (TA) measurement was conducted by the automatic potentiometric titrator (Metrohm 877 titrino plus, Switzerland) using 1% NaOH titrating the diluted aril juice. Crude protein was determined with a UV spectrophotometer (GBC Cintra 404, Australia). The aril was crushed after dipping with liquid nitrogen and 1.0 g was blended with 0.1 g of $CuSO_4$, 1 g of K_2SO_4 and 5 mL of H_2SO_4, and then the mixture was heated for 0.5 h. Cooled liquid was diluted to 100 mL, out of which 2 mL was mixed with 1–2 drops of *p*-nitrophenol, which were neutralized with NaOH (300 g/L) solution to yellow appearance and then acetic acid solution (1 mol/L) to achromatism. An aliquot (0.5 mL) of the resultant solution was mixed with 4 mL of sodium acetate-acetate buffer solution (3:2, pH 4.8) and 4 mL of visualization reagent (100 mL diluent of 15 mL of 37% formaldehyde and 7.8 mL of acetylacetone), and then heated for 15 min in water bath at 100 °C. After cooling, absorbance of the sample was determined at 400 nm. The test was repeated 3 times. Content of the crude protein was measured by the relative specification curve with the following formula (GB5009.5-2010, 2010).

$$X = \frac{C - C_0}{m \times \frac{V_2}{V} \times \frac{V_4}{V} \times 1000 \times 1000} \times 100 \times F \quad (1)$$

where X was the content of the crude protein (g/100 g); C was the nitrogen content of the sample (μg); C_0 was the nitrogen content of the blank solution (μg); V was the constant volume of the sample

Table 1
Picking time and sensory evaluation values of litchi fruit from three provinces in China.

Fujian province			Guangxi province			Yunnan province		
Cultivar	Time	SEV	Cultivar	Time	SEV	Cultivar	Time	SEV
Guiwei	2011.07.24	89.59	Sanyuehong	2011.06.04	74.62	Mangshi	2011.06.28	83.11
Shuangjianyuhebao	2011.07.24	83.37	Feizixiao	2011.06.18	81.17	Dahongpao	2011.06.28	84.89
Chenzi	2011.07.24	83.20	Baitangying	2011.06.24	84.95	Feizixiao	2011.06.28	81.33
Yuanhong	2011.07.24	79.83	Dazao	2011.06.23	85.81	Nuomici	2011.06.28	81.67
Hushanwanli	2011.07.25	86.37	Jiaoli	2011.07.19	88.37	Baila1	2011.06.28	79.87
Nuomici	2011.07.22	91.20	Heli	2011.07.16	81.11	Baila2	2011.06.28	85.50
Jidi	2011.07.22	83.17	Jizui	2011.07.15	86.11	Daheiye	2011.06.28	79.27
Guangming	2011.07.22	75.57	Sanguihong	2011.07.08	87.78			
Huaizhi	2011.07.22	83.64	Mili	2011.07.09	80.64			
Xiafanzhi	2011.08.01	82.93	Baitangli	2011.07.20	90.63			
Midingxiang	2011.07.22	79.30						
Jinzhong	2011.07.24	80.47						