The Main Evaluation Indicators for the Quality of Fruit Radish

Weiling YUAN, Lei CUI, Caixia GAN, Xiaohui DENG, Zhengming QIU*

Economic Crop Research Institute, Hubei Academy of Agricultural Sciences, Wuhan 430064, China

Abstract The aim of this study was to establish a scientific evaluation system for fruit radish quality. 8 quality indicators were measured for 23 varieties, such as Meinong, Qiaotouqing and Chunbulao. The indicators included root weight, root shape index, water content, crispness, soluble solids, crude fiber, isothiocyanate and vitamin C. These data were analyzed by variation correlation analysis, principal component analysis and system cluster analysis. 23 varieties of fruit radish were analyzed by variation correlation; 8 indicators were compressed into 6 integrated variables using principal component analysis. Finally, the main evaluation indicators of fruit radish were determined by using cluster analysis and correlation analysis. The results indicated that the range of variation coefficient was from 1.64% - 89.99%. Water content, crispness, soluble solids, crude fiber, isothiocyanate were the important components of fruit radish quality, playing a major role in the quality. These 8 indicators were closely related and relatively independent. Water content was significantly and positively correlated with crispness; soluble solids and crude fiber were significantly and negatively related to vitamin C; crispness was significantly and positively correlated with crude fiber and vitamin C. Based on the above results, 4 representative indicators were used for evaluating fruit radish quality, that is water content, crispness, soluble solids, crude fiber, which could reflect the most information of fruit radish quality.

Key words Fruit radish, Quality, Evaluation indicators, Principal component analysis, Systematic cluster analysis

1 Introduction

Fruit radish is crisp and juicy, sweet and refreshing, with dense fleshy tissue. It has special medicinal efficacy and rich nutrition. With the development of people's living standards, the high-quality fruit radish is increasingly favored by consumers. Quality is the main factor determining the market competitiveness of fruit radish, and there are many factors affecting quality such as sensory quality, flavor and nutritional quality, which brings difficulty to comprehensive evaluation[1-3]. Therefore, it is necessary to research the fruit radish quality indicators and establish a scientific evaluation system for fruit radish quality, in order to effectively select the high-quality fruit radish. Fruit radish has a special flavor and is usually evaluated by tasting. However, the tasting-based evaluation is the qualitative method and involves the participation of many people, and the appraisal results are susceptible to human factors[4-9]. Although some people have explored the evaluation indicators for fruit radish flavor, it is not systematic and there are many problems such as few varieties, incomplete coverage of indicators and lack of exploration on relationship between indicators[1]. In this study, with 23 fruit radish varieties as materials, we did principal component analysis and cluster analysis on 8 indicators including root weight, root shape index, water content, crispness, soluble solids, crude fiber, isothiocyanate and vitamin C. The suitable evaluation indicators for fruit radish quality were selected to provide the theoretical basis for establishing the scientific evaluation indicator system for fruit radish quality.

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* Corresponding author. E-mail: qiusunmoon@163.com

2 Materials and methods

2.1 Materials and reagents The experiment was done in the vegetable test base of Hubei Academy of Agricultural Sciences during 2014 - 2015. There were a total of 23 test varieties of fruit radish, and the samples were collected from the radish resource garden in Economic Crop Research Institute, Hubei Academy of Agricultural Sciences. It was sampled during radish maturity period, and 3 samples were selected for each variety and combination. Each sample was repeated three times, and the results were denoted by mean.

2.2 Determination methods The root weight and root shape index were directly determined; water content was determined by the general drying method; crispness was determined by GY-1 fruit durometer; crude fiber was determined by plant food crude fiber GB/T 5009.10 - 2003 method; isothiocyanate was determined by high performance liquid chromatography (NY/T1103.3 - 2006); vitamin C was determined by 2, 6-dichloro indophenol titration method; soluble solids were determined by GB 12295 - 90 refractometer method.

2.3 Data analysis Test results were expressed as the average of 3 replicates measured at each time. The DPS software was used for principal component analysis, correlation analysis and cluster analysis.

3 Results

3.1 Comparison of fruit radish quality indicators The quality traits of different fruit radish were shown in Table 1. From Table 1, it was found that there was large variation in the main quality traits of fruit radish varieties, and the variation in water content was smallest, ranging from 89.50% to 94.87%. The average water content was 92.39%, and the coefficient of variation was 1.64%. There was the largest variation in isothiocyanate content

between different varieties, in the range of 0 – 4.3 mg/100g. The average content was 1.21 mg/100 g, and the coefficient of variation was 89.99%. It was followed by root shape index, with coefficient of variation of 61.64%, indicating that there was rich genetic diversity and selection potential in fruit radish varieties. There was a small difference in crispness, soluble solids and crude fiber between different varieties, with coefficient of variation of 10.22%, 14.87% and 10.59%, respectively.

Table 1 The quality traits of different fruit radish varieties

Varieties	Root weight g	Root shape index	Water content %	Crispness kg/cm^2	Soluble solids %	Isothiocyanate mg/100 g	Crude fiber %	Vitamin C mg/100 g
L35-4A121	166.70	2.81	94.51	8.20	3.26	2.25	0.90	9.70
L30-5-2-2	165.20	2.84	94.87	7.40	4.24	1.37	0.90	4.30
L35-9-2	98.30	1.93	92.92	9.30	5.76	1.09	0.90	12.80
234-Y-2	150.80	0.88	94.25	10.80	4.76	0.00	1.00	12.00
B12	163.20	0.87	92.65	9.00	4.76	1.42	1.00	7.50
B-97	265.70	0.79	94.40	8.60	3.91	1.38	0.70	3.80
B96-1	136.80	0.86	94.60	9.20	4.66	1.38	0.80	2.50
Meinong	180.90	2.82	93.17	8.20	4.71	0.26	0.90	28.80
Chunbulao	124.90	2.77	93.91	9.40	5.81	0.56	0.70	19.50
217-1-2-38	389.20	1.83	92.48	7.10	5.71	3.15	0.80	17.30
2011M-102	253.50	0.82	89.50	7.20	5.71	1.02	0.90	26.80
2011M045-1	230.20	0.89	90.52	8.60	5.71	1.07	0.90	17.60
2011M052-2	203.60	0.79	91.55	9.90	6.51	0.00	1.10	20.80
2011M062-1	168.90	0.85	91.91	7.70	5.51	1.30	0.9	21.30
56-1	165.80	0.85	92.32	8.50	5.21	0.64	0.90	17.60
L56-2	145.60	0.83	92.34	8.60	4.91	1.13	0.90	17.20
M06-0-2	154.60	0.84	91.72	9.20	4.21	0.00	0.90	16.10
L55-6	254.30	0.83	91.63	9.50	5.81	1.14	0.90	11.20
L47-1	265.30	0.87	91.87	8.60	5.61	0.41	1.00	16.40
L52-1	198.60	0.79	91.82	7.90	5.11	2.96	1.00	22.70
Qiaotouqing	365.80	2.83	90.30	8.00	5.81	0.00	0.80	13.60
L53-7-1	118.70	0.84	91.58	8.40	5.71	0.96	0.90	7.60
L42-16	246.80	0.85	90.22	8.70	5.71	4.33	1.00	18.60
Coefficient of variation//%	36.97	61.64	1.64	10.22	14.87	89.99	10.59	46.80

Note: $CV = S/X \times 100\%$, where CV is coefficient of variation, S stands for standard deviation and X is mean value.

3.2 Correlation analysis Table 2 showed the correlation analysis results of fruit radish quality traits. As shown in Table 2, root weight was significantly and positively correlated with water content, but not significantly correlated with root shape index, soluble solids, isothiocyanate, crude fiber and vitamin C; root shape index was not significantly correlated with other indicators; water content was significantly and positively correlated with crispness, but significantly and negatively correlated with soluble solids, crude fiber and vitamin C; crispness was significantly and positively correlated with crude fiber, but not significantly correlated with other indicators; soluble solids were significantly and positively correlated with crude fiber and vitamin C; isothiocyanate was not significantly correlated with other indicators; crude fiber was significantly and positively correlated with vitamin C. In summary, in the 23 test samples, the greater the root weight, the higher the water content; the higher the water content, the crisper the fleshy root, the lower the content of soluble solids, crude fiber and vitamin C.

Table 2 Correlation analysis on the main quality traits of fruit radish

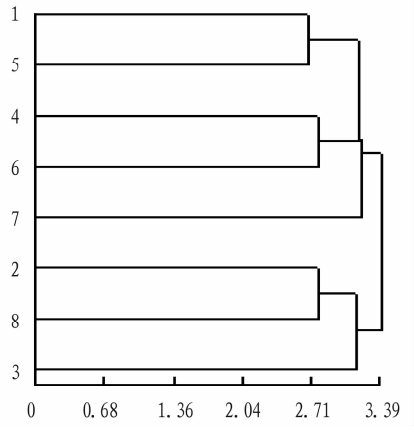
Varieties	Root weight	Root shape index	Water content	Crispness	Soluble solids	Isothiocyanate	Crude fiber	Vitamin C
Root weight	1	0.05	0.42**	−0.12	0.26	0.24	0.16	0.15
Root shape index		1.00	0.36	0.27	−0.21	−0.07	−0.39	0.01
Water content			1.00	0.63**	−0.65**	−0.07	−0.28*	−0.54**
Crispness				1.00	0.07	−0.04	0.24*	−0.06
Soluble solids					1.00	−0.07	0.21*	0.44**
Isothiocyanate						1.00	0.03	−0.03
Crude fiber							1.00	0.26*
Vitamin C								1.00

Note: ** indicates a significant correlation at the 0.01 level; * indicates a significant correlation at the 0.05 level.

2.3 Principal component analysis Based on the principle of cumulative variance contribution rate of not less than 90%, 6 principal components were selected. The main factors determining the size of the first principal component were water content, soluble solids and crude fiber, indicating that the internal quality condition of fruit radish fleshy roots played the most important role in the quality evaluation; the main factors determining the size of the second principal component were crispness, isothiocyanate and crude fiber; the main factors determining the size of the third principal component were water content, crispness, isothiocyanate and soluble solids; the main factors determining the size of the fourth principal component were vitamin C, root weight and crude fiber; the main factors determining the size of the fifth principal component were root shape index, crispness and soluble solids; the main factors determining the size of the sixth principal component were crude fiber and water content. Root weight appeared only in the fourth principal component; root shape index appeared only in the fifth principal component; water content appeared only in the first, third and sixth principal components; crispness appeared in the second, third and fifth principal components at the same time; soluble solids appeared in the first, third and fifth principal components at the same time; isothiocyanate appeared in the second and third principal components at the same time; crude fiber appeared in the first, second, fourth and sixth principal components; vitamin C appeared in the fourth principal component. This indicated that water content, crispness, soluble solids, crude fiber and isothiocyanate were important components determining the fruit radish quality and played a major role in fruit radish quality.

Table 3 Eigenvector, contribution rate and cumulative contribution rate of 8 principal components

Varieties	Factor 1 (Z_1)	Factor 2 (Z_2)	Factor 3 (Z_3)	Factor 4 (Z_4)	Factor 5 (Z_5)	Factor 6 (Z_6)	Factor 7 (Z_7)	Factor 8 (Z_8)
	Root weight	Root shape index	water content	Crispness	Soluble solids	Isothiocyanate	Crude fiber	Vitamin C
Root weight	0.3068	0.2298	-0.0001	-0.4638	0.0516	0.2937	0.3581	0.1505
Root shape index	-0.2328	0.1873	-0.3023	0.3424	0.4918	0.2496	-0.1815	-0.2985
Water content	-0.5773	0.0044	0.5196	0.1073	0.2000	0.5228	0.2493	0.7431
Crispness	-0.1522	-0.5972	-0.5906	-0.2545	0.4151	0.0681	0.4941	-0.3552
Soluble solids	0.4765	-0.1303	-0.5670	-0.2623	0.5199	-0.3146	-0.3085	0.3890
Isothiocyanate	0.0970	0.3441	0.6893	0.1647	0.1835	-0.2836	0.1814	-0.1509
Crude fiber	0.4632	-0.4158	0.3022	0.4490	0.1488	0.6042	-0.2326	0.1536
Vitamin C	0.2354	0.0186	-0.3182	0.5421	-0.1298	-0.1887	0.5919	0.1104
Root weight	31.7400	23.7700	14.5000	10.7300	6.4600	6.2300	4.2600	2.2900
Root shape index	31.7400	55.5100	70.0100	80.7400	87.2100	93.4400	97.7100	100.0000



Note: 1. root weight; 2. root shape index; 3. water content; 4. crispness; 5. soluble solids; 6. isothiocyanate; 7. crude fiber; 8. vitamin C.

Fig. 1 The cluster dendrogram of 8 evaluation factors

2.4 Cluster analysis The group average method was used for hierarchical clustering, and the cluster analysis was performed on the eigenvectors of the first six principal components in Table 2. Root weight and soluble solids were clustered together, and crispness and isothiocyanate were clustered together, indicating that the two sets of variables were at the similar level, and they were clustered with crude fiber into a group, clustered with root shape index and vitamin C into a group, clustered with water content into a group. There was a close correlation between fruit radish quality factors which were clustered into a group, and a factor could be selected to represent other factors for simplification; the factors of a single class were relatively independent. Thus, the above fruit radish quality evaluation factors should be root weight or soluble solids; crispness or isothiocyanate; root shape index or vitamin C, water content, crude fiber. Based on the principal component analysis and cluster analysis results, it was found that water content, crispness, soluble solids and crude fiber were important components determining the fruit radish quality and playing the main role in fruit radish quality.

3 Conclusions and discussions

China has more than 80 high-quality local varieties of fruit radish, mainly distributed in Shandong, Jiangsu, Hebei, Anhui and other places[3]. The study found that the fruit radish varieties had rich genetic diversity in the traits of root weight, root shape index, water content, crispness, soluble solids, crude fiber, isothiocyanate and vitamin C. The trait with the lowest coefficient of variation was water content (1.64%) while the trait with the highest coefficient of variation was isothiocyanate (89.99%), which indicated the differences in evolutionary conservation and genetic plasticity of different fruit radish traits, and if there was great variation in fleshy root traits, the genetic attribute of traits would be rich, there would be great potential for selection, and there would be high probability of breeding new varieties and species[4]. Through the correlation analysis, the correlation between fruit radish quality

traits was obtained, which provided the theoretical basis for the breeding of new varieties of fruit radish. The determination of vitamin C was more time-consuming and laborious than that of root weight, soluble solids, crispness and root shape index, and the correlation between indicators indicated that vitamin C was significantly correlated with soluble solids and crude fiber, so we could determine soluble solids and crude fiber to generally judge the content of vitamin C. 4 factors (water content, crispness, soluble solids, crude fiber) were finally selected for evaluation of fruit radish quality. The results showed that the cumulative contribution rate of 4 evaluation factors reached 80.74%, which satisfied the principle of cumulative contribution rate of the first r principal components reaching 80%, having been able to represent all the information. The principal component analysis translates many indicators into several indicators, and cluster analysis classifies a group of samples or variables according to closeness in the nature[10]. They have become important means of quality evaluation[11-15]. In this study, we conducted principal component analysis and cluster analysis on 23 fruit radish samples, and the 4 evaluation factors could meet the evaluation requirements, so the 4 evaluation factors finally determined could be used for comprehensive evaluation of different fruit radish varieties, greatly simplifying the evaluation of fruit radish quality. The 8 quality evaluation indicators selected in this paper were dominated by the intrinsic quality of fruit radish, and we did not evaluate fleshy root color, gloss and other external qualities. In order to more comprehensively and reasonably evaluate the fruit radish quality and breed high-quality new varieties, it is necessary to further study on how to simplify fruit radish quality evaluation indicators.

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