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Full Length Article

Analysis and Evaluation of Quality Traits of Peanut Varieties with Near Infra-red Spectroscopy Technology

Hong Liu[1,2], Manish K. Pandey[3], Zhenjiang Xu[1], Dehua Rao[1], Zhanquan Huang[1], Mengqiang Chen[1], Defeng Feng[1], Rajeev K. Varshney[3] and Yanbin Hong[2,4*]
[1]*College of Agriculture, South China Agricultural University, Guangzhou-510642, China*
[2]*Crops Research Institute, Guangdong Academy of Agricultural Sciences, Guangzhou-510640, China*
[3]*International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad-500324, India*
[4]*Guangdong Provincial Key Laboratory of Crops Genetics and Improvement, Guangzhou-510640, China*
[*]For correspondence: hongyanbin@gdaas.cn

Abstract

Peanut kernel and oil quality are the important features which decide the market value of the produce. In order to identify better source with good kernel and oil quality for use in breeding program, 21 quality traits of 100 peanut varieties were phenotyped under national official field tests in South China. Some of these traits included were contents of crude fat, protein, fatty acids and amino acids using near infra-red spectroscopy technology. The average contents of crude fat, protein, amino acids, oleic and linoleic in these varieties were found to be 51.37%, 26.31%, 22.611%, 44.84% and 34.05%, respectively. The principal component analysis (PCA) identified three component factors representing 74% variation with the clear-cut grouping of 21 quality traits into these component factors i.e., protein and amino acid (PC1), unsaturated fatty acid (PC2) and crude fat (PC3). Furthermore, the cluster analysis divided these 100 peanut varieties into 4 groups with some differences in the quality traits between groups. It is an effective way to comprehensively evaluate the peanut quality by principal component analysis and cluster analysis, which could not only avoid the bias and the instability of single factor analysis, but also explore a practical distinction way for the peanut quality analysis and the quality breeding. © 2019 Friends Science Publishers

Keywords: Peanut; Quality traits; Principal components analysis; Cluster analysis

Introduction

Peanut (*Arachis hypogaea* L.) is the world's fourth leading oil crop and the third leading source of vegetable protein in terms of consumption volume. The peanut kernels contain 38 ~ 60% of fat (mainly unsaturated fatty acids) and 24~36% of protein containing all the 8 essential amino acids with high as 90% digestibility coefficient (Ramachandran *et al*., 2007; Jamdar *et al*., 2010). With the changing consumers' preference and quality demand for preparing diversifying peanut products and preparations in recent years, peanut breeders in major peanut-producing countries such as China have changed the previous yield-oriented breeding strategy to new criteria that put equal weight on both yield and quality traits in order to regain dominance in international market.

Quality breeding of peanut involves numerous traits with complicated interactive relationships; therefore the quality traits of different genotypes must be monitored (traced) from early generations. New rapid and low-cost none-destructive seed quality assay technologies in place of conventional chemical assay approaches are required to perform early generation phenotyping of breeding material. In this context, the Near Infrared Spectroscopy (NIRS) seems the best available option which is a physical assay technology developed in the end of last century for the qualitative and quantitative determination of organic substances (Blanco and Villarroya, 2002). It has been widely applied as the rapid, cost-effective and none-destructive assay of quality traits of various of crops, including rice, wheat and corn (Tallada *et al*., 2009; Agelet *et al*., 2012; González-Martín *et al*., 2014; Bagchi *et al*., 2016; Oblath *et al*., 2016). In the recent years, with the establishment of NIRS models for determination of protein, amino acids, crude fat and fatty acids etc., NIRS technology has gradually become an indispensable tool in the quality breeding and food processing of peanut (Ghosh *et al*., 2016). Wang *et al*. (2013) successfully used NIRS combined with multivariate calibration to determine the protein and amino acid contents of peanuts. The NIRS technique was also deployed to determinate acid value in peanut oil (Rao *et al*., 2009; Yang *et al*., 2017). In recent, Jiang *et al*. (2016) used Near-Infrared hyperspectral images to identify moldy peanuts with accuracy of 98.73%.

The most of the studies on peanut quality traits have focused on the establishment of NIRS determination models,

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or on the variation analysis of individual traits, with an apparent lack of comprehensive evaluations of peanut quality traits. Obviously, insufficient information of peanut quality traits has become a major hindrance for breeding of high quality peanut varieties. The purpose of this study is to deploy NIRS technology to make a comprehensive assay of the main quality traits of 100 peanut varieties that have been tested in the south China regional peanut variety tests during 2001-2015 through principal component and cluster analysis. The information generated about peanut quality traits on a set of varieties will provide new strategy for peanut breeding.

Materials and Methods

The Experimental Materials

The 100 peanut varieties panel included the varieties used in the South China regional peanut trials during 2001-2015. The seeds of these varieties were provided by the Crop Research Institute of Guangdong Academy of Agricultural Science, China (Table 1).

Experimental Methods

Field experimental design: The peanut varieties were sown in 2016/03/08 in the experimental and demonstration farm of the Crop Research Institute of Guangdong Academy of Agricultural Sciences. Randomized block experimental design was adopted with three replications and single seeds of each variety was sown with plant to plant spacing of 20 cm in two rows of 2 m in length and row to row spacing of 35 cm.

Determination of Quality Traits

Matured peanut pods were harvested and sun dried before being shelled. Twenty full kernels (seeds) of each variety were randomly selected for performing quality traits analysis using DA7200 Diode Array NIR Spectrometer Food Analyzer Grain Analyzer (Perten, Switzerland). Three plots of kernels (seeds) for each variety were determined to obtain the mean value. The 21 quality traits determined include total protein content, total amino acid content, the content of valine, isoleucine, lysine, leucine, histidine, threonine, methionine, phenylalanine, arginine, proline, crude fat content, and the content of fatty acids oleic acid, linoleic, O/L, stearic, palmitic, docosanamide, tetracosanoic acid, arachidic acid, as well as the O/L ratio.

Statistical Analysis

The statistical package for the Social Sciences (SPSS) 19.0 (IBM, USA) was used for data analysis such as correlation analysis, principal component analysis and cluster analysis (sum of square of deviation method, genetic distance was expressed in Euclidean distance).

Results

Quality Traits Analysis of Tested Peanut Varieties

Crude fat content: The crude fat content of the tested peanut varieties ranged from 46.87% to 55.26%, with an average value of 51.37% and a small coefficient of variance of 2.84% (Table 2). Crude fat content was mainly distributed between 49.0% ~ 53.0%, a total of 92 varieties, accounting for 92% of the test varieties. There are 5 varieties (Longhua 106, Longhua 243, Minhua 15, Shanyou 162, Yunhuasheng 4) with less than 49.0% crude fat content, accounting for 5% of the total, while only a single variety (Zhongkaihua 4) had more than 55.0%.

Fatty Acids Contents

The oleic acid content of the tested peanut varieties had a normal distribution ranging from 39.32% to 82.53%, with an average of 44.84% and a coefficient of variance of 12.41% (Table 2). Total 83% of the varieties had an oleic acid content ranging from 40% ~ 46%, with only one variety (Guihua 35) had a high value of larger than 60% (Fig. 1). The linoleic content of the tested peanut varieties had a non-normal distribution ranging from 2.85% to 39.04%, with an average of 34.05% and a coefficient of variance of 13.93%. Total 85% of the varieties had linoleic acid content ranging from 32% to 38%. Among the 5 saturated fatty acids determined in this study, the content of palmitic was the highest, ranging from 8.50% to 12.91%, with an average of 10.51% and a coefficient of variance of 8.95%. The next highest saturated fatty acid was docosanamide, which ranged from 0.67% to 6.18%, and averaged 3.40% with a coefficient of variance of 27.34%. The content of stearic acid had an average value of 1.14% and demonstrated the largest coefficient of variance of 62.63%, with its value ranging from 0.01% to 3.44%. The content of arachidic acid and tetracosanoic acid were low, that the former had an average of 0.853% with a coefficient of 26.49% and the latter had an average of 2.011% with a coefficient of 28.29%.

The oleic/linoleic (O/L) ratio is an important indicator of storability of peanut or peanut products, larger ratios predict better storability and longer shelf lives (Nepote *et al*., 2009). Results of this study indicated that oleic/linoleic (O/L) ratio of the peanut varieties varied largely from 1.01 ~ 28.96 with an average of 1.69 and a high coefficient of variance of 192.2%. It can be seen from the frequency distribution histogram (Fig. 1) that the O/L ratio of most (89 of the varieties) concentrated in the range of 1.0 ~ 1.4, 11 of the varieties had larger than 1.5 O/L ratios, and 3 varieties had larger than 2.0 O/L ratios, among which the cultivar Guihua 35 had an extraordinary high O/L ratio of 29 which raised the overall average O/L ratio and coefficient of variance. If Guihua 35 were excluded from the calculation, the average would be 1.31 with a normal coefficient of variance of 19.4%.

Table 1: Names and sources of the peanut varieties

Variety	Breeding institution	Province
Yueyou 7, Yueyou 9, Yueyou 13, Yueyou 18, Yueyou 29, Yueyou 35, Yueyou 40, Yueyou 41, Yueyou 45, Yueyou 49, Yueyou 52, Yueyou 290, Yueyou 390, Yueyou 410, Yueyou 645, Hanghua 2, Hanghua 3	Guangdong Academy of Agricultural Sciences	Guangdong
Shanyou 21, Shanyou 52, Shanyou 71-31, Shanyou 162, Shanyou 188, Shanyou 250, Shanyou 382, Shanyou 851, Shanyoufu 1, Shanyouyou 1	Shantou Agricultural Science Research Institute	Guangdong
Zhongkaihua 1, Zhongkaihua 2, Zhongkaihua 4, Zhongkaihua 6, Zhongkaihua 9, Zhongkaihua 10, Zhongkaihua 99	Zhongkai University of Agriculture and Engineering	Guangdong
Zhanhong 3, Zhanyou 15, Zhanyou 16, Zhanyou 55, Zhanyou 58, Zhanyou 62, Zhanyou 65, Zhanyou 75, Zhanyou 82, Zhanyou 93	Zhanjiang Academy of Agricultural Sciences	Guangdong
Quanhua 052, Quanhua 511, Quanhua 551, Quanhua 557, Quanhua 627, Quanhua 701, Quanhua 726, Quanhua 2197	Quanzhou Agricultural Science Research Institute	Fujian
Minhua 2, Minhua 5, Minhua 7, Minhua 8, Minhua 9, Minhua 10, Minhua 13, Minhua 15, Jinhua 44, Jinhua 47	Fujian Agriculture and Forestry University	Fujian
Longhua 6, Longhua 9, Longhua 18, Longhua 106, Longhua 163, Longhua 202, Longhua 243	Longyan Agricultural Science Research Institute	Fujian
Puhua 1, Puhua 3, Puhua 21, Puhua 23, Puhua 25	Putian Agricultural Science Research Institute	Fujian
Fuhua 4, Fuhua 6, Fuhua 8	Fujian Academy of Agricultural Sciences	Fujian
Guihua 026-10, Guihua 026-7, Guihua 24, Guihua 26, Guihua 35, Guihua 56-20, Guihua 68, Guihua 69, Guihua 193, Guihua 771, Guihua 836	Guangxi Academy of Agricultural Sciences	Guangxi
Heyou 8, Heyou 9, Heyou 10, Heyou 11, Heyou 12, Heyou 13, Heyou 14, Heyou 15	Hezhou Agricultural Science Research Institute	Guangxi
Xianghua 120, Xianghua 2008	Hunan Agricultural University	Hunan
Yunhuasheng 4, Yunhuasheng 12	Yunnan Academy of Agricultural Sciences	Yunnan

Table 2: Quality traits of the peanut varieties

Quality Traits	Min (%)	Max (%)	Mean (%)	SD (%)	CV (%)
Oil	46.87	55.26	51.37	1.459	2.84
Protein	22.99	29.43	26.31	1.310	4.98
Amino acids	17.38	26.34	22.61	1.911	8.45
Oleic acid	39.32	82.53	44.84	5.565	12.41
Linoleic acid	2.85	39.04	34.05	4.743	13.93
O/L ratio	1.01	28.96	1.69	3.251	192.22
Palmitic acid	8.50	12.91	10.51	0.941	8.95
Stearic acid	0.01	3.44	1.140	0.714	62.63
Arachidic acid	0.46	1.61	0.853	0.226	26.49
Docosanamide	0.67	6.18	3.402	0.930	27.34
Tetracosanoic acid	0.54	3.33	2.011	0.569	28.29
Threonine	0.61	0.96	0.777	0.076	9.78
Valine	0.85	1.32	1.042	0.112	10.75
Methionine	0.21	0.31	0.253	0.020	7.91
Isoleucine	0.49	0.77	0.657	0.057	8.68
Leucine	1.15	1.76	1.519	0.129	8.49
Phenylalanine	0.97	1.40	1.222	0.094	7.69
Lysine	0.20	1.30	0.707	0.205	29.00
Histidine	0.71	0.98	0.847	0.052	6.14
Arginine	1.77	3.05	2.513	0.272	10.82
Proline	0.60	1.77	1.216	0.198	16.28

SD=Standard deviation; CV= Co-efficient of variation

Protein Contents

The protein contents of the kernels of the tested varieties ranged from 22.99% to 29.43% with an average of 26.31% and a coefficient of variance of 4.98% (Fig. 1). Apparently, the protein content had a larger variance among the peanuts as compared with crude fat content. Total 86% of the varieties had a protein content between 24.0% to 27.0%; seven of the varieties (Yueyou 410, Puhua 25, Quanhua 551, Heyou 12, Longhua 9, Longhua 106, Yunhuasheng 12) had a higher than 28.0% protein content and four of which (Guihua 69, Zhongkaihua 4, Heyou 10, Heyou 11) had a lower than 20.0% protein contents.

Amino Acid Content

The total amino acid content of the kernels of the tested varieties ranged from 17.38% to 26.34% with an average of 22.611% and a coefficient of variance of 8.45% (Table 2). Among the 10 amino acids, the contents of arginine were the highest which ranged from 1.77% to 3.05% with an average value of 2.513%, and the contents of methionine were the lowest which Ranged from 0.21% to 0.31% with an average value of 0.253%; lysine demonstrated the largest coefficient of variance of 29.00%, which was far higher than other amino acids. There are 3 varieties with more than 3% arginine content, namely Yueyou 410, Quanhua 551 and Longhua 9.

Correlation Among Peanut Quality Traits

Multiple significant correlations were detected between different quality traits. The protein content and total amino acids were significantly negatively correlated with crude fat content (Table 3).

Table 3: Correlation coefficients among the quality traits

Trait	Oil	Protein	Amino acids	Oleic acid	Linoleic acid	O/L ratio	Palmitic acid	Stearic acid	Arachidicacid	Docosa-namide	Tetracosa-noic acid	Threonine	Valine	Methion-ine	Isoleucine	Leucine	Phenyla-lanine	Lysine	Histidine	Arginine	Proline
Oil	1.000																				
Protein	-0.273**	1.000																			
Amino acids	-0.274**	0.996**	1.000																		
Oleic acid	0.047	-0.056	-0.039	1.000																	
Linoleic acid	-0.215*	0.153	0.137	-0.943**	1.000																
O/L ratio	0.161	-0.085	-0.07	0.966**	-0.970**	1.000															
Palmitic acid	0.422**	-0.162	-0.158	-0.719**	0.531**	-0.620**	1.000														
Stearic acid	0.037	0.213*	0.171	-0.107	-0.012	-0.053	-0.017	1.000													
Arachidic acid	-0.154	0.483**	0.441**	-0.062	0.066	-0.065	-0.264**	0.887**	1.000												
Docosanamide	0.285**	-0.236*	-0.223*	-0.061	0.009	-0.023	0.323**	-0.342**	-0.403**	1.000											
Tetracosanoic acid	0.026	-0.111	-0.099	0.039	0.024	0.025	0.029	-0.574**	-0.454**	0.873**	1.000										
Threonine	-0.076	0.551**	0.556**	-0.009	0.119	-0.05	-0.135	-0.343**	-0.078	-0.069	0.214*	1.000									
Valine	-0.432**	0.704**	0.691**	0.013	0.158	-0.058	-0.449**	-0.026	0.361**	-0.103	0.241*	0.724**	1.000								
Methionine	-0.526**	0.791**	0.796**	-0.024	0.116	-0.073	-0.287**	0.350**	0.588**	-0.357**	-0.203*	0.272**	0.650**	1.000							
Isoleucine	-0.131	0.975**	0.973**	-0.012	0.058	-0.013	-0.078	0.274**	0.470**	-0.191	-0.144	0.496**	0.592**	0.738**	1.000						
Leucine	-0.177	0.991**	0.993**	-0.019	0.094	-0.035	-0.118	0.206*	0.445**	-0.199*	-0.115	0.540**	0.642**	0.760**	0.990**	1.000					
Phenylalanine	-0.284**	0.992**	0.995**	-0.073	0.15	-0.093	-0.119	0.210*	0.453**	-0.218*	-0.121	0.524**	0.664**	0.798**	0.975**	0.990**	1.000				
Lysine	0.05	0.237*	0.240*	-0.073	0.015	-0.054	0.145	0.320**	0.197*	-0.478**	-0.667**	-0.008	-0.229*	0.118	0.294**	0.268**	0.265**	1.000			
Histidine	-0.363**	0.498**	0.536**	-0.257**	0.339**	-0.272**	-0.001	-0.446**	-0.226*	0.104	0.318**	0.519**	0.533**	0.372**	0.407**	0.485**	0.546**	-0.109	1.000		
Arginine	-0.238*	0.991**	0.987**	-0.101	0.172	-0.118	-0.092	0.286**	0.512**	-0.230*	-0.157	0.493**	0.641**	0.793**	0.986**	0.990**	0.990**	0.285**	0.459**	1.000	
Proline	0.300**	-0.116	-0.057	-0.17	0.073	-0.111	0.524**	-0.561**	-0.701**	0.463**	0.340**	0.142	-0.299**	-0.316**	-0.056	-0.035	-0.034	-0.023	0.503**	-0.101	1.000

Oleic content was significantly negatively correlated with linoleic content with a high correlation coefficient of -0.943 (*P<0.05*). Oleic content was not correlated with most of the saturated fatty acids, except that it was significantly negatively correlated with palmitic with a correlation coefficient of -0.719 (*P<0.05*). Positive or negative correlations existed between different saturated fatty acids. For example, palmitic had a significant positive coefficient of correlation of 0.887 (*P<0.05*) with arachidic acid, and a significant negative coefficient of correlation of -0.574 (*P<0.05*) tetracosanoic acid. Most of amino acids were positively correlated with other amino acids, except that proline which negatively correlated with others.

Principal Component Analysis of Peanut Quality Traits

The comprehensive quality of the peanut varieties was difficult to evaluate since the quality traits were too numerous and complicatedly correlated with each other. Therefore, principal component analysis was performed to all the 21 quality traits to know the extent of variation and bring out strong patterns in a dataset. All the first 3 components had larger than 3 eigenvalues, and their cumulative percent reached up to 74.47%, therefore these could be used to evaluate peanut quality in place of the above 21 traits (Table 4). The first component, which accounts for a cumulative percent of 39.79%, was composed mainly of protein and amino acids, with all the eigenvectors of protein, total amino acids, phenylalanine, arginine, leucine and isoleucine being larger than 0.9, therefore the first component could be regarded as the protein and amino acid factor. The second component had a cumulative percent of 18.8% and was contributed mainly by oleic and O/L ratio, therefore it could be referred to as the factor of unsaturated fatty acids. The third component had a cumulative percent of 15.8% and was contributed mainly by crude fat content; hence it could be termed the factor of crude fat.

The principal component scores of each variety were calculated according to their eigenvalues and eigenvectors which ranked in a high to low order to evaluate the weight of each component in a variety. Results indicated that the variety Yueyou 410 had the highest score for the protein and amino acid factor, Guihua 35 had the highest score for the factor of unsaturated fatty acids, and Zhongkaihua 4 had the highest score for the factor of crude fat.

Peanut quality should be evaluated by a comprehensive evaluation of all quality traits rather than by individual traits. The comprehensive score of each variety was obtained by addition of the scores of the first three principal components.

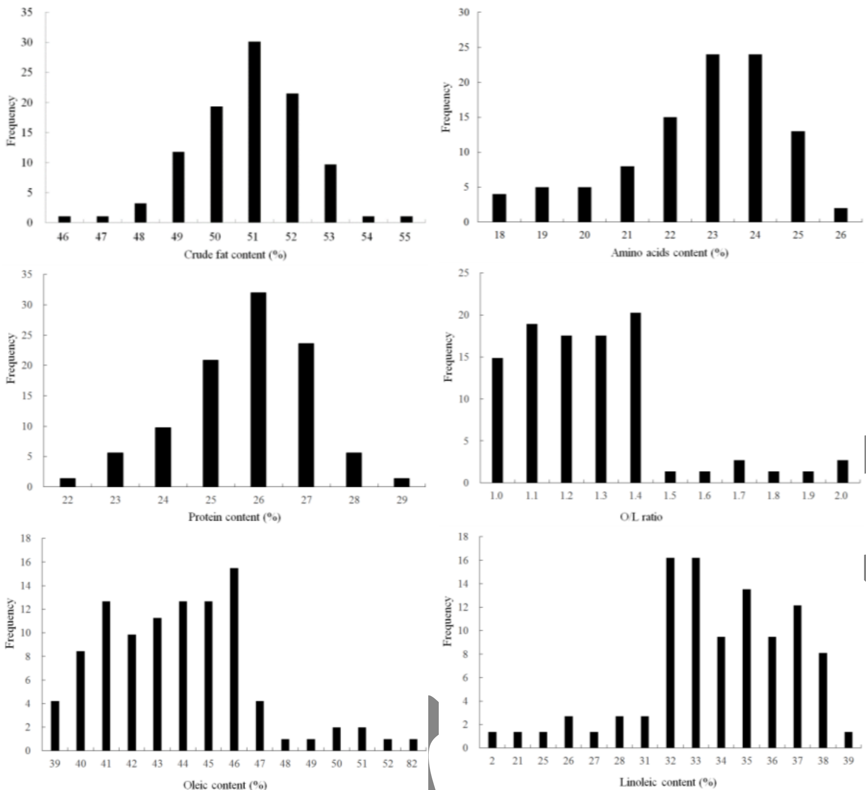

Fig. 1: The frequency distributions of crude fat content, O/L ratio, protein content and amino acids content

Table 4: Principal component analysis of quality traits in peanut

Trait	Eigenvector		
	Component 1	Component 2	Component 3
Oil	-0.369	-0.048	0.655
Protein	0.982	0.059	0.111
Amino acids	0.976	0.088	0.139
Oleic acid	-0.084	0.786	0.167
Linoleic acid	0.186	-0.679	-0.330
O/L ratio	-0.121	0.750	0.269
Palmitic acid	-0.221	-0.609	0.397
Stearic acid	0.288	-0.531	0.001
Arachidic acid	0.565	-0.358	-0.216
Docosanamide	-0.341	0.300	0.050
Tetracosanoic acid	-0.193	0.548	-0.238
Threonine	0.541	0.349	0.026
Valine	0.748	0.329	-0.441
Methionine	0.859	-0.013	-0.210
Isoleucine	0.940	0.050	0.278
Leucine	0.959	0.082	0.229
Phenylalanine	0.975	0.047	0.156
Lysine	0.255	-0.422	0.545
Histidine	0.490	0.228	-0.070
Arginine	0.974	-0.019	0.161
Proline	-0.208	0.145	0.536
Eigenvalue	8.357	3.964	3.317
Variance (%)	39.8	18.9	15.8
Cumulative percent (%)	39.8	58.7	74.5

The top 10 varieties with the highest comprehensive scores were Longhua 9, Yueyou 410, Minhua 7, Heyou 12, Fuhua 4, Guihua 68, Yueyou 7, Longhua 18, Guihua 026-10 and Yunhuasheng 12 (Table 5). Each of the top 10 varieties had at least one principal component to have high scores. For example, Longhua 9, which had the highest comprehensive score, had the second highest score in the protein factor, the 10th highest score in the crude fat content factor and the 37th highest in the unsaturated fatty acid factor.

Cluster Analysis of Peanut Varieties

Cluster analysis of the 100 peanut varieties based on the 21 quality traits revealed that the varieties could be integrated into 4 groups as the genetic distance threshold was set to be 12 (Fig. 2). Group I comprised of 57 varieties (57% of all trialed varieties) include mainly the series of Yueyou, Shanyou, Zhongkaihua, Minhua, Fuhua and Heyou. The mean values of quality traits of Group I was close to the overall mean value of all trialed varieties. Group II comprised of 19 varieties from mainly the series of Longhua, Puhua and Quanhua etc., this group was characterized with higher than average protein content and amino acid content. Group III comprised of 22 varieties from mainly the series of Zhanyou and Guihua, which was characterized with higher than average crude fat and oleic acid. Group IV comprised of only two varieties of Yunhua series and had lower than average crude fat content, palmitic and stearic acids.

Table 5: Top 10 peanut varieties of principal components value

Variety	Component 1	Component 2	Component 3	Synthetic component
Yueyou 410	4.56/3*	0.83/37	2.49/10	3.18/1
Longhua 9	6.52/1	-2.16/85	-0.1/45	2.92/2
Minhua 7	2.82/17	0.37/48	4.23/4	2.50/3
Heyou 12	3.97/5	0.92/35	-0.2/49	2.31/4
Fuhua 4	2.84/16	1.13/30	2.08/12	2.25/5
Guihua 68	2.26/25	1.98/16	1.94/13	2.12/6
Yueyou 7	3.93/7	-0.03/58	-1.01/73	1.88/7
Longhua 18	2.87/15	0.51/45	0.9/30	1.85/8
Guihua 026-10	3.22/12	0.54/44	-0.02/43	1.85/9
Yunhuasheng 12	4.22/4	0.02/58	-1.93/84	1.85/10

*Dates in the table mean score/order

Discussion

Advantages of NIRS in Determination of Quality Traits

In this study, by using the built-in peanut quality prediction model of Perten DA7200 Diode Array NIR Spectrometer Food Analyzer Grain Analyzer, only 15 h were spent for the determination of 21 quality traits each with 3 replicates of 100 peanut varieties, relatively less time than traditional method. Compared with traditional methods, the NIRS technique possesses the following advantages: (1) simple and fast, did not require tedious pre-treament and chemical reactions, which greatly shortens determination time; (2) many quality traits can be determined simultaneously with high efficiency; (3) low cost of only personnel and instrumental wearing charges; (4) precision of determination shall be increased with the data accumulation and the optimization of models; (5) applicable quality traits can be broadened (Roggo *et al*., 2007).

Variation of Quality Traits Among Peanut Varieties

Results indicated that individual quality traits had significant larger coefficients of variation than comprehensive quality traits. For example, the content of stearic and lysine had as high as 62.63% and 29.00%, respectively coefficient of variation, but crude fat and protein contents had small as 2.84% and 4.98%, respectively coefficient of variation. This means that comprehensive quality traits are more difficult to be genetically improved than individual quality traits.

According to Yin *et al.* (2011), the quality traits of 51 most widely cultivated peanut varieties in China (including those cultivated in northern provinces) had larger coefficients of variation than those cultivated in South China. For example, the coefficients of variation of protein content and crude fat content were high as 21.69% and 11.21%, respectively. The smaller coefficients of variation of quality traits of South China trialed varieties was indicative of their narrow genetic background which may hinder the breeding breakthrough in peanut varieties, and new germplasm resources from northern areas or abroad must be introduced.

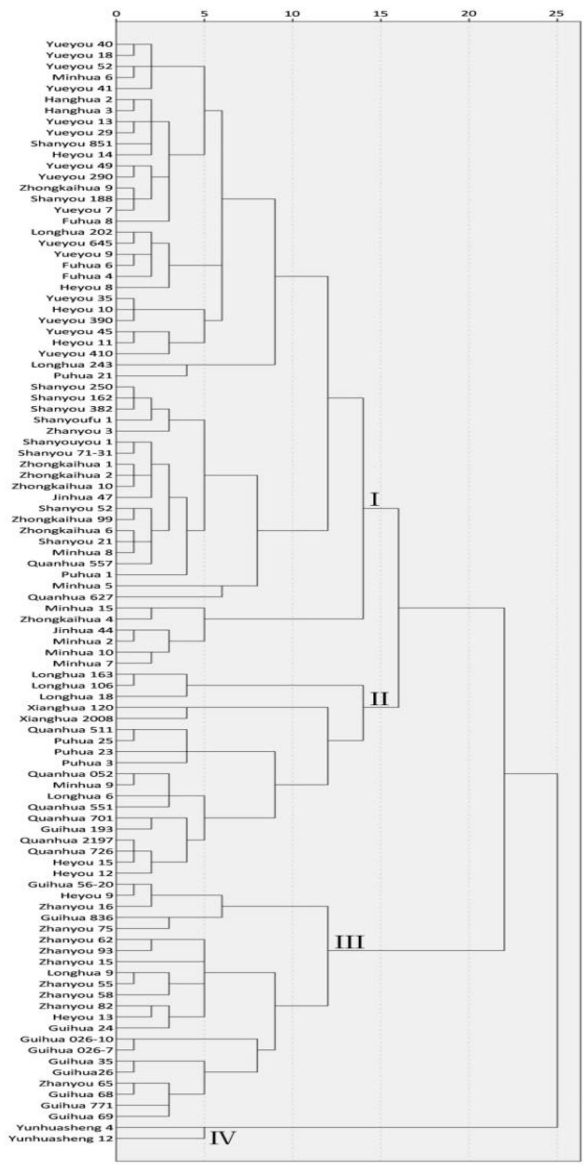

Fig. 2: Cluster analysis of 100 peanut varieties

Oleic acid content is an important index of peanut oil quality as it provide increased shelf life and health benefits to manufacturers and consumers, respectively (Isleib *et al*., 2006). The oleic acid content of the trialed varieties in this study ranged from 39.32% to 82.53% with the mean value being 44.84%, and only variety Guihua 35 had an oleic acid content of over 60% (82.53%). This indicates that the oleic acid content of the South China trialed varieties has yet far reached the high oleic acid criterion, which discloses an important research orientation for peanut breeders in South China.

Comprehensive Evaluation of Peanut Quality with Principal Component Analysis

Comprehensive evaluation on peanut main quality traits can provide the basis for peanut quality breeding and production. Yin *et al.* (2011) performed principal component analysis of 10 quality traits in 51 peanut varieties. The results showed that the 10 traits were consolidated into 4 independent factors which accounted for 80.73% of total variation. In our principal component analysis of 21 quality traits, the 3 independent factors (the protein and amino acid factor, the unsaturated fatty acid factor and the crude fat factor) represented 74.47% of information of the original data, therefore could be satisfactorily used to evaluate the comprehensive quality of peanut varieties.

Peanut protein is rich in essential amino acids; a high score of the first principal component represents a high nutritive value. Therefore, in breeding high-protein peanut varieties for food use purposes, the first component will be offered more weights in selection. A high score of the second component represents high oleic acid content and a high O/L ratio, hence a higher quality of the oil. A high score of the third component represents a high crude fat content. Therefore, in breeding oil-producing purpose peanut varieties, the second and third components will be given more weights in selection.

Mining of Superior Peanut Germplasm and their Utilization

The variation extent of the progeny depends largely on the remoteness of the genetic relationship of the parents, the remoter the parental relationship, the greater the variation and hybrid vigor in progeny. Therefore, identification of the genetic relationship of different materials is a pre-requisite of selecting proper parents. In this study, cluster analysis based on the sum of square of deviation was applied to 100 trialed peanut varieties which were integrated into 5 groups. Since lines or varieties from different group have larger genetic differences than those from the same group, parental materials should be chosen from different groups to breed offspring possessing better traits and adaptability over their parents. Gur and Zamir (2004) evaluated the progress in breeding for increased tomato (*Solanum lycopersicum*) yield using genotypes carrying a pyramid of three independent yield-promoting genomic regions introduced from the drought-tolerant green-fruited wild species *Solanum pennellii*. Yield of hybrids parented by the pyramided genotypes was more than 50% higher than a control market leader variety under both wet and dry field conditions which received 10% of the irrigation water.

It can be seen from the results of cluster analysis that peanut varieties bred by the same breeding institution tended to be integrated into one group, indicating the consistent and limited usage of the genetic materials. But there were exceptions that varieties from one breeding institution belonged to different groups, which resulted from the more frequent than before exchange of breeding materials among different institutions.

Conclusion

The smaller coefficients of variation of quality traits of South China trialed varieties indicated their narrow genetic background. Principal component analysis and cluster analysis can better evaluate quality traits of peanut varieties.

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