Chapter 3
Quality Characteristics of Peanut Products

Peanut processing and consumption patterns vary in different countries. In the United States, 57% of peanuts are used for peanut butter, about 23% for roasted peanut, 19% for desserts and ingredients, and only 1% for oil; in China, 53% of peanuts are used for oil extraction, 40% for food, 3% for exports, and 4% for seed reservation. At present, the main peanut-processed products in China include peanut oil, peanut protein (powder), peanut-texturized protein, peanut beverage, peanut butter, and peanut candy. The annual output of peanut oil is about 2.5 million tons, and its annual consumption accounts for 8% of the total edible oil; meanwhile, the total content of unsaturated fatty acid is more than 85%, which is very similar to the fatty acid composition of olive oil. With the efficacy of reducing the incidence of cardiovascular disease, it is known as "Chinese olive oil", so peanut oil has been the leading domestic peanut-processed products and the research focus in the field of peanut processing. At the same time, in recent years, with the promotion of peanut oil cold pressing technology, the deep development and utilization of peanut protein have aroused domestic attention, especially the preparation, structure, and functional evaluation of peanut protein, and the influence of different varieties of protein components and subunit contents on the gel property, solubility, emulsibility, and other functional properties has increasingly become the research focus in this field. Based on the research of the processing characteristics of different peanut varieties, the team systematically studied the functional properties of peanut protein such as preparation, gelation, and solubility, as well as the composition and oxidation stability of peanut oil, and analyzed the processing characteristics of peanut oil, peanut protein, and other main peanut-processed products, so as to provide China's peanut processing enterprises with technical support to produce high-quality peanut-processed products.

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1 Quality Characteristics of Separated Protein from Peanut

This team prepared separated protein from peanut using 66 different peanut varieties and the same alkali-soluble acid deposition processing technology, as well as conducted assay determination for 12 quality indicators (Table 3.1) for preparing the separated protein from peanut, including sensory quality, physicochemical and nutritional quality, and processing quality. The results are shown in Table 3.2.

1.1 Edible Quality

Sensory evaluation results indicated that the color of peanut protein is milky white, the shape is powder, and the difference between the peanut varieties is not significant. Therefore, the sensory quality of peanut protein will not be analyzed in detail.

1.2 Physicochemical and Nutritional Quality

According to the figures shown in Table 3.2, the coefficients of variation of crude fat and crude fiber were 63.56% and 77.57%, respectively, which indicated that the crude fat and crude fiber of different peanut protein isolate were different. It was found by comparing mean and median in different varieties that the differences of crude fat and crude fiber were 10.32% and 17.86%, respectively; the median of other qualities was close to their means, which indicated that the outliers of these data were few. The coefficient of variation of protein purity was small (2.10%), with a variation range of 85.64–94.81%, which was consistent with the research results (88.69–94.22%) of Kim et al. (1992).

1.3 Processing Quality

The analysis results of water holding capacity, oil holding capacity, hardness, elasticity, cohesion, solubility, and other main processing quality characteristics for separated protein from peanut are shown in Table 3.3. It can be seen that the coefficient of variation of oil holding capacity is 8.89%, which is small, indicating that their dispersion degree is insignificant; the variation range of peanut protein solubility is 57.63–93.44%. Compared with other literatures, the protein solubility of the peanut varieties selected in this research is better than that in other researches. For example, Berardi and Cherry (1981) found that the variation range of solubility of separated protein from peanut was 15.1–55.6%; Madhavi et al. (1989) found that

Table 3.1 Quality characteristics of separated protein from peanut

Sensory quality		Physicochemical and nutritional quality				Processing quality					
Color and luster	Shape	Crude fat	Purity of protein	Ash content	Crude fiber	Gelation					Solubility
						Hardness	Elasticity	Cohesion	Water holding capacity	Oil holding capacity	

Table 3.2 Physicochemical and nutritional quality analysis of separated protein from peanut

	Range of variation/%	Mean/%	Standard deviation	Upper quartile/%	Median/%	Lower quartile/%	Coefficient of variation/%	Data variation/%
Ash content	0.74–2.35	1.35	0.32	1.11	1.32	1.50	24.09	2.22
Crude fat	0.54–8.84	2.52	1.60	1.35	2.26	3.26	63.56	10.32
Crude fiber	0.00–1.02	0.28	0.22	0.14	0.23	0.34	77.57	17.86
Purity of protein	85.64–94.81	90.57	1.90	89.44	90.51	91.89	2.10	0.07

Table 3.3 Analysis of processing quality of separated protein from peanut

	Variation range/%	Mean/%	Standard deviation	Upper quartile/%	Median/%	Lower quartile/%	Coefficient of variation/%	Data variation/%
Water holding capacity	0.74–1.38	1.07	0.18	0.94	1.08	1.23	16.90	0.93
Oil holding capacity	1.04–1.71	1.34	0.12	1.26	1.33	1.42	8.89	0.75
Hardness	0.37–4.26	1.60	0.86	0.91	1.60	2.09	53.37	0.00
Elasticity	0.53–0.97	0.75	0.11	0.68	0.75	0.82	15.09	0.00
Cohesion	0.28–0.59	0.39	0.06	0.35	0.39	0.43	15.04	0.00
Solubility	57.63–93.44	79.33	9.43	81.91	80.12	76.76	11.89	0.97

the solubility of separated protein from peanut was 33.073%. The variation range of water holding capacity of peanut protein is 0.74–1.38%, which is lower than that in the researches of Berardi and Cherry (1981) and Ihekoronye (1986). The results show that the variation range of water holding capacity of separated protein from peanut is 1.30–1.60% water/g separated protein.

1.4 Correlation Between Quality Characteristics

It was found through correlation analysis (Table 2 of Appendix 3) that the solubility of protein showed a significant negative correlation with the hardness ($r = -0.687$) and cohesion ($r = -0.588$) of protein solubility and gelation, indicating that the varieties with good protein solubility may have poor gelation. This result is similar to that of Li (2009), and these factors may be related to the composition, structure, and subunit content of protein.

1.5 Evaluation Method of Gelation

The gelation of peanut protein is often evaluated by two aspects of texture and other indicators (water holding capacity, oil holding capacity). Texture property is the main indicator to evaluate the gelation of proteins. The greater the hardness, elasticity, and cohesion are, the better the texture property is. At present, there is no uniform method for evaluating the gelation of peanut protein. The evaluation may be conducted by analyzing the hardness, or the three texture indicators or texture indicators, and water holding capacity and oil holding capacity. This book has conducted in-depth analysis on the relationship between the above indicators to determine the evaluation method of gelation.

1.5.1 Evaluation Indicators

Texture is related to brittle, crisp, hard, slippery, sticky, and other mechanical sensory properties of gel, and it may indicate the state of gel from the appearance. Szczesniak (1963) divided the texture property into three main categories: mechanical, geometric, and others (fat and moisture). The evaluation of texture analyzer (TPA) on food is based on the three categories above, which are actually three stages at which texture properties are perceived, namely, first bite (initial stage), chewing (second stage), and remaining (third stage). TPA consists of analog test equipment, which may produce a number of instrument parameters for the purpose of simulating the parameters produced during the human chewing process (Szczesniak 2002). Szczesniak (1963) studied the relationship between sensory results and texture characteristics. The results showed that there was a significant

Table 3.4 Analysis of correlation between texture indicator and other indicators

	Water holding capacity	Oil holding capacity
Water holding capacity	1.000	
Oil holding capacity	−0.360	1.000
Hardness	0.120	−0.080
Elasticity	−0.170	−0.070
Cohesion	0.390	−0.108

positive correlation between the viscosity of sensory evaluators and that of TPA ($r = 0.89$, $P = 0.054$), and there was a significant positive correlation between the cohesion of sensory evaluators and that of TPA ($r = 0.89$, $P = 0.045$), so TPA data may be very effective in evaluating the gelation of food (Dubost 2001).

The correlation between texture indicators and water holding capacity and oil holding capacity was analyzed (Table 3.4). It was shown from the table that the correlation value among water holding capacity, oil holding capacity, and three texture indicators was very small, while texture characteristic was the important indicator to evaluate the gelation of protein, so the gelation of protein was evaluated by analysis of the three texture indicators.

1.5.2 Evaluation Equation

Texture indicator is the main parameter for the evaluation of gelation. The greater the three indicators are, the better the values are. In order to get a unified evaluation method, the three indicators should be normalized into an indicator to reflect the problems.

1.5.2.1 Outlier of Hardness, Elasticity, and Cohesion

Boxplot method was used to analyze the outlier of hardness, elasticity, and cohesion of 66 peanut varieties in Table 3.1. It was found from Fig. 3.1 that there was an outlier in hardness (Huayu 19), one outlier in cohesion (Yueyou 40), while no outlier in elasticity. Based on the removal of these two indicator outliers, the original data became 64 varieties for follow-up analysis.

1.5.2.2 Normalization Method: Adopt Formula

Define m of indicators to be $(x_{i,1}, x_{i,2}, x_{i,3} n x_{i,m})$ $i = 1, 2, \ldots, n$ $(n = 40)$, respectively, and obtain matrix Z:

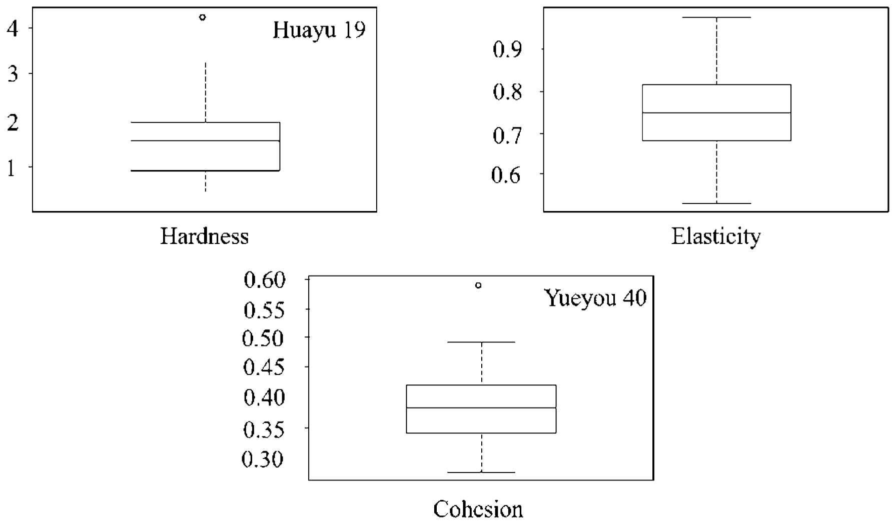

Fig. 3.1 Analysis of outlier of texture indicator

$$Z = \begin{pmatrix} x_{1,1} & x_{1,2} & x_{1,3} \\ x_{2,1} & x_{2,2} & x_{2,3} \\ n & n & n \\ x_{n,1} & x_{n,2} & x_{n,3} \end{pmatrix} \tag{3.1}$$

Standardize matrix Z to obtain matrix Z:

$$Z = \begin{pmatrix} x_{1,1} & x_{1,2} & x_{1,3} \\ x_{2,1} & x_{2,2} & x_{2,3} \\ n & n & n \\ x_{n,1} & x_{n,2} & x_{n,3} \end{pmatrix} \tag{3.2}$$

where $x_{i,j} = \frac{x_{i,j} - \bar{x}_j}{s_j}, \bar{x}_j = \frac{1}{n}\sum_{k=1}^{n} x_{k,j}, s_j = \sqrt{\frac{1}{n-1}\sum_{k=1}^{n}\left(x_{k,j} - \bar{x}_j\right)^2}, i = 1, 2, n, n,$ $j = 1, 2, 3.$

On the basis of Z, two matrixes were established, respectively, **S** and **W**, where

$$S = \begin{pmatrix} s_{1,1} & s_{1,2} & n & s_{1,n} \\ s_{2,1} & s_{2,2} & n & s_{2,n} \\ n & n & n & n \\ s_{n,1} & s_{n,2} & n & s_{n,n} \end{pmatrix} \tag{3.3}$$

$$s_{ij} = e^{-\sqrt{(x_{i1}-x_{j1})^2+(x_{i2}-x_{j2})^2+(x_{i3}-x_{j3})^2}}, i = 1, 2, n, n, j = 1, 2, 3,$$

and

$$W = \begin{pmatrix} \sum_{i=1}^{n} s_{i,1} & 0 & n & 0 \\ 0 & \sum_{i=1}^{n} s_{i,2} & n & 0 \\ n & n & n & n \\ 0 & 0 & n & \sum_{i=1}^{n} s_{i,n} \end{pmatrix} \tag{3.4}$$

$P = W^{-1}S$, where W^{-1} is the inverse matrix of W.

Transform the three indicators for evaluating gelation texture into one indicator using Formulas 3.1–3.4, that is, transform the three-dimensional data of gelation into one-dimensional data, and define the three-dimensional data as the comprehensive value of gelation of peanut protein.

1.5.2.3 Correlation Between Comprehensive Value of Gelation and Original Indicator

Analyze the correlation between the comprehensive value of gelation and three indicators of gelation texture (Table 3.5).

It was found through correlation analysis that the maximum correlation coefficient between the comprehensive value of gelation and hardness was 0.87, and the correlation coefficient with elasticity and cohesion was relatively small, but all of them were positively correlated. The results were in good agreement with the requirements that the greater the gelation hardness, elasticity, and cohesion were, the better they were, indicating that the gelation obtained by this method is accurate and reliable.

1.5.2.4 Establishment of Evaluation Equation of Comprehensive Value of Gelation

Regression analysis was made for hardness, elasticity, and cohesion based on the normalized data, and the equation obtained was

$$\text{Gelation} = 0.0268 + 0.1618 \times \text{hardness} + 0.3781 \times \text{elasticity} + 1.1573 \times \text{cohesion} \tag{3.5}$$

Table 3.5 Analysis of correlation between the comprehensive value of gelation and other texture indicators

	Gelation		Gelation
Gelation	1.00	Elasticity	0.41
Hardness	0.87	Cohesion	0.47

Table 3.6 Quality characteristics of peanut oil

	Evaluation indicators
Sensory quality	Color, taste, and transparency
Physicochemical and nutritional quality	Moisture and volatile matter, specific gravity, refractive index, unsaponifiable matter
Processing quality	Induction time, peroxide value, acid value, iodine value, saponification value

2 Peanut Oil Quality Characteristics

There are rich peanut resources in China, and the difference in the quality of different peanut varieties affects the quality of peanut oil. We have analyzed and determined the 12 indicators (Table 3.6) related to the sensory quality, physicochemical and nutritional quality, and processing quality of 45 different peanut varieties in China's main production areas.

2.1 Edible Quality

The determination (color was measured by Lovibond test method, with reference to GB/T5525-85) and statistical analysis of sensory quality of 45 varieties of peanut oil are shown in Table 3.7. It can be seen that different varieties of peanut oil had the inherent smell and taste of peanut oil, without significant difference. However, the 45 varieties all processed were yellowish and transparent. Of them, the variation range of red value is 0.40–1.70, and the variation range of yellow value is 2.80–13.00; meanwhile, the color difference between different varieties was large, and the variation coefficients of red value and yellow value were, respectively, 39.92% and 43.15%.

2.2 Physicochemical and Nutritional Quality

The determination and statistical analysis of water, volatile matter, and unsaponifiable matter content for the peanut oil processed from 45 varieties of peanut are shown in Table 3.8. It can be seen that the variation range of water and

Table 3.7 Color of different varieties of peanut oil

No.	Name	Color		No.	Name	Color	
		Red	Yellow			Red	Yellow
1	Zhonghua 8	0.65 ± 0.07	11.00 ± 0.00	26	Black peanut	0.55 ± 0.07	5.10 ± 0.28
2	Sanhua 7	0.40 ± 0.00	3.50 ± 0.00	27	034–256-1	0.70 ± 0.00	6.45 ± 0.07
3	Silihong	0.60 ± 0.00	2.80 ± 0.00	28	Jihua 9814	0.80 ± 0.00	10.50 ± 0.78
4	Luhua 11	0.70 ± 0.00	5.50 ± 0.00	29	Yuhua 15	0.70 ± 0.00	5.50 ± 0.00
5	Bianhua 3	0.90 ± 0.00	9.25 ± 0.21	30	Yuhua 9326	0.60 ± 0.07	4.40 ± 0.07
6	Haihua 1	0.65 ± 0.07	4.40 ± 0.00	31	Yuhua 9327	0.90 ± 0.00	6.10 ± 0.07
7	Shuangji 2	0.40 ± 0.00	5.35 ± 0.07	32	Kainong 30	0.50 ± 0.00	9.90 ± 0.00
8	Shanhua 9	0.85 ± 0.07	3.35 ± 0.07	33	Kainong 37	0.80 ± 0.00	4.00 ± 0.00
9	Fenghua 5	0.45 ± 0.07	4.30 ± 0.28	34	Yuanza 9102	0.50 ± 0.00	5.40 ± 0.00
10	White peanut	0.60 ± 0.14	3.95 ± 0.07	35	Heyou 11	1.05 ± 0.35	4.35 ± 0.49
11	Fenghua 1	0.60 ± 0.00	4.40 ± 0.00	36	Guihua 771	1.20 ± 0.00	8.05 ± 0.07
12	Fenghua 3	0.70 ± 0.00	6.50 ± 0.00	37	Yueyou 86	1.25 ± 0.78	11.45 ± 2.19
13	Fenghua 4	1.70 ± 0.00	13.00 ± 0.00	38	Shanyou 250	1.25 ± 0.07	6.90 ± 0.71
14	Xuhua 5	0.70 ± 0.00	5.40 ± 0.00	39	Zhanhua 82	0.90 ± 0.00	12.00 ± 0.00
15	Yuanhua 8	0.80 ± 0.00	6.50 ± 0.00	40	Pearl red	1.15 ± 0.21	11.00 ± 0.00
16	Xuhua 13	0.65 ± 0.07	7.35 ± 0.07	41	Longhua 243	1.00 ± 0.00	6.35 ± 0.21
17	Xuhua 14	0.70 ± 0.00	6.40 ± 0.00	42	Yueyou 14	1.00 ± 0.14	5.70 ± 0.71
18	Huayu 19	0.55 ± 0.07	3.35 ± 0.07	43	Minhua 9	0.85 ± 0.35	5.90 ± 0.95
19	Huayu 20	0.45 ± 0.07	3.25 ± 0.07	44	Yueyou 45	1.55 ± 0.07	6.85 ± 0.21
20	Huayu 22	0.60 ± 0.00	5.70 ± 0.00	45	Yueyou 40	1.70 ± 0.00	13.00 ± 0.00
21	Huayu 23	0.60 ± 0.00	6.20 ± 0.00		Average value	0.79	6.65
22	Huayu 28	0.60 ± 0.00	13.00 ± 0.00		Maximum value	1.70	13.00
23	Huayu 31	0.60 ± 0.00	5.35 ± 0.07		Minimum value	0.40	2.80
24	Baisha 1016	0.55 ± 0.07	5.30 ± 0.14		Variation coefficient %	39.92	43.15
25	Colorful peanut	0.80 ± 0.00	5.20 ± 0.00				

Table 3.8 Physicochemical and nutritional quality indicators of different varieties of peanut oil

No.	Name	Water and volatile matter %	Unsaponifiable matter g/kg	No.	Name	Water and volatile matter %	Unsaponifiable matter g/kg
1	Zhonghua 8	0.07 ± 0.00	4.24 ± 0.49	26	Black peanut	0.08 ± 0.01	17.21 ± 2.03
2	Shanhua 7	0.05 ± 0.01	19.76 ± 1.23	27	034–256-1	0.06 ± 0.02	9.47 ± 1.43
3	Silihong	0.08 ± 0.00	12.10 ± 1.22	28	Jihua 9814	0.11 ± 0.01	11.76 ± 0.76
4	Luhua 11	0.11 ± 0.02	9.74 ± 1.54	29	Yuhua 15	0.09 ± 0.01	8.22 ± 0.83
5	Bianhua 3	0.09 ± 0.01	13.23 ± 0.98	30	Yuhua 9326	0.08 ± 0.01	10.66 ± 1.28
6	Haihua 1	0.09 ± 0.00	10.24 ± 0.67	31	Yuhua 9327	0.07 ± 0.00	12.23 ± 3.02
7	Shuangji 2	0.05 ± 0.04	9.67 ± 1.29	32	Kainong 30	0.05 ± 0.04	10.02 ± 1.79
8	Shanhua 9	0.15 ± 0.01	11.70 ± 1.12	33	Kainong 37	0.11 ± 0.13	17.32 ± 2.83
9	Fenghua 5	0.20 ± 0.00	17.91 ± 2.00	34	Yuanza 9102	0.05 ± 0.05	18.65 ± 1.91
10	White peanut	0.08 ± 0.04	10.95 ± 0.97	35	Heyou 11	0.15 ± 0.03	
11	Fenghua 1号	0.04 ± 0.00	8.95 ± 1.72	36	Guihua 771	0.22 ± 0.02	
12	Fenghua 3	0.08 ± 0.00	6.08 ± 1.02	37	Yueyou 86	0.20 ± 0.01	
13	Fenghua 4	0.08 ± 0.00	9.14 ± 2.00	38	Shanyou 250	0.16 ± 0.04	
14	Xuhua 5	0.07 ± 0.00	7.70 ± 1.23	39	Zhanhua 82	0.18 ± 0.01	
15	Yuanhua 8	0.09 ± 0.00	9.00 ± 2.01	40	Pearl red	0.16 ± 0.01	
16	Xuhua 13	0.05 ± 0.01	11.28 ± 1.78	41	Longhua 243	0.20 ± 0.03	
17	Xuhua 14	0.06 ± 0.02	11.57 ± 1.02	42	Yueyou 14	0.16 ± 0.01	
18	Huayu 19	0.07 ± 0.00	11.13 ± 1.09	43	Minhua 9	0.15 ± 0.01	
19	Huayu 20	0.05 ± 0.03	10.66 ± 1.46	44	Yueyou 45	0.18 ± 0.01	
20	Huayu 22	0.04 ± 0.01	8.01 ± 0.29	45	Yueyou 40	0.16 ± 0.01	
21	Huayu 23	0.08 ± 0.01	6.34 ± 0.54		Average value	0.10	11.39
22	Huayu 28	0.07 ± 0.01	9.70 ± 1.43		Maximum value	0.22	19.76
23	Huayu 31	0.10 ± 0.00	13.61 ± 0.98		Minimum value	0.04	4.24
24	Baisha 1016	0.06 ± 0.01	18.83 ± 1.71		Variation coefficient %	49.74	33.31
25	Colorful peanut	0.08 ± 0.00	10.05 ± 1.98				

volatile matter was 0.04–0.22%, and the difference between varieties was large, and the variation coefficient was 49.74%. The variation range of unsaponifiable matter was 4.24–19.76 g/kg, and the variation coefficient was 33.31%, which was large.

2.3 Processing Quality

The analysis results of five processing quality indicators (including peroxide value, acid value) for 45 varieties of peanut oil are shown in Table 3.9. It can be seen that the variation ranges of peroxide value, acid value, induction time, iodine value, and saponification value of 45 varieties were 0.31–4.95 mmol/kg, 0.22–2.57 mgKOH/g, 3.59–5.76 h, 88.13–116.14 g/100 g, and 148.47–217.13 mg/g, respectively. The variation coefficients of indicators were large, the variation coefficient of peroxide value was 56.04%, and the variation coefficient of acid value was 96.78%, indicating that there was large difference in the quality of peanut oil processed from different varieties of peanut.

We determined the oxidation induction time of different varieties of peanut oil at 120 °C using Rancimat oil oxidation stabilizer and comparatively studied the oxidation stability of different varieties of peanut oil. The oxidation induction curve of peanut oil is shown in Fig. 3.2. Carboxylic acid and other volatile substances were generated after oil oxidation, Rancimat method was used to automatically draw the change curve of conductivity with time by testing the change in conductivity caused due to the abovementioned volatile matters, and thus the induction time under accelerated oxidation conditions was calculated. Induction time was used to represent the oxidation stability of oil; the longer the induction time was, the better the oil oxidation stability was; the shorter the induction time was, the worse the oil oxidation stability was. It was found from Table 3.9 that there was a significant difference ($P < 0.01$) in the oxidation induction time between different varieties of peanut oil tested, the average induction time was 4.53 h, the variation amplitude was 2.17 h, and the variation coefficient was 12.04%. Among them, the peanut oil variety with the longest induction time was Shanhua 7, being 5.76 h; the peanut oil variety with the shortest induction time was Yuhua 15, being 3.59 h. According to Worthington et al. (1972), there was difference in the oxidation stability of oil processed from 82 different genotypes of peanut, which was similar to the results of this book. The length of the induction time reflected the stability of oil oxidation (Josep 1993), and the above analysis showed that among 45 peanut oil varieties, the oil oxidation stability of Shanhua 7 was the best.

2.4 Correlation Between Quality Characteristics

We determined the indicators of sensory quality, physicochemical and nutritional quality, and processing quality of 45 varieties of peanut oil and conducted

Table 3.9 Processing quality indicators of different varieties of peanut oil

No.	Name	Peroxide value mmol/kg	Acid value mgKOH/g	Induction value h	Iodine value g/100 g	Saponification value mg/g
1	Zhonghua 8	2.72 ± 0.11	0.62 ± 0.41	4.19 ± 0.06	88.14 ± 0.03	177.33 ± 0.11
2	Shanhua 7	2.24 ± 0.55	0.27 ± 0.00	5.76 ± 0.07	96.88 ± 0.12	176.18 ± 0.10
3	Silihong	2.70 ± 0.01	0.36 ± 0.00	5.19 ± 0.16	97.63 ± 0.01	170.65 ± 0.06
4	Luhua 11	3.28 ± 0.05	0.33 ± 0.02	4.67 ± 0.10	93.16 ± 0.03	175.64 ± 0.00
5	Bianhua 3	2.20 ± 0.01	0.64 ± 0.03	4.61 ± 0.10	93.22 ± 0.07	148.48 ± 0.09
6	Haihua 1	3.08 ± 0.02	0.27 ± 0.03	5.23 ± 0.17	90.18 ± 0.21	177.34 ± 0.01
7	Shuangji 2	2.57 ± 0.49	0.31 ± 0.00	4.45 ± 0.09	92.63 ± 0.02	170.98 ± 0.07
8	Shanhua 9	2.97 ± 0.18	0.28 ± 0.00	4.39 ± 0.14	98.07 ± 0.19	174.85 ± 0.12
9	Fenghua 5	2.37 ± 0.02	0.36 ± 0.01	3.74 ± 0.27	93.15 ± 0.12	176.73 ± 0.19
10	White peanut	2.13 ± 1.21	2.57 ± 0.01	4.62 ± 0.16	97.25 ± 0.08	175.49 ± 0.13
11	Fenghua 1	3.07 ± 0.44	0.38 ± 0.01	3.91 ± 0.24	96.25 ± 0.12	175.49 ± 0.08
12	Fenghua 3	2.45 ± 0.00	0.42 ± 0.01	3.91 ± 0.03	91.79 ± 0.07	177.18 ± 0.01
13	Fenghua 4	1.04 ± 0.03	0.32 ± 0.01	4.37 ± 0.09	88.69 ± 0.06	177.18 ± 0.23
14	Xuhua 5	2.73 ± 0.00	0.39 ± 0.06	3.81 ± 0.06	93.04 ± 0.13	166.79 ± 0.09
15	Yuanhua 8	3.72 ± 0.06	0.36 ± 0.04	3.73 ± 0.03	100.92 ± 0.11	186.27 ± 0.00
16	Xuhua 13	3.41 ± 0.44	0.37 ± 0.02	3.82 ± 0.23	101.70 ± 0.13	188.28 ± 0.01
17	Xuhua 14	3.77 ± 0.13	1.05 ± 0.01	4.27 ± 0.10	101.85 ± 0.05	186.27 ± 0.12
18	Huayu 19	3.23 ± 0.03	0.41 ± 0.02	4.71 ± 0.09	98.64 ± 0.10	183.63 ± 0.10
19	Huayu 20	2.04 ± 0.20	0.39 ± 0.00	4.63 ± 0.04	98.27 ± 0.03	181.99 ± 0.02
20	Huayu 22	3.23 ± 0.06	0.41 ± 0.01	4.79 ± 0.13	94.16 ± 0.00	186.54 ± 0.04
21	Huayu 23	2.19 ± 0.04	0.67 ± 0.03	5.63 ± 0.11	99.15 ± 0.12	183.27 ± 0.05
22	Huayu 28	2.08 ± 0.03	0.54 ± 0.01	3.94 ± 0.07	92.59 ± 0.04	181.52 ± 0.07
23	Huayu 31	1.41 ± 0.22	0.37 ± 0.01	4.44 ± 0.14	100.53 ± 0.05	185.64 ± 0.19
24	Baisha 1016	2.27 ± 0.06	0.36 ± 0.01	4.36 ± 0.07	108.98 ± 0.06	187.58 ± 0.23
25	Colorful peanut	0.81 ± 0.01	1.20 ± 0.00	4.97 ± 0.26	103.69 ± 0.11	181.14 ± 0.21
26	Black peanut	2.89 ± 0.25	0.53 ± 0.04	4.81 ± 0.06	103.96 ± 0.13	185.92 ± 0.08

27	034-256-1	3.13 ± 0.34	0.38 ± 0.00	5.23 ± 0.17	96.16 ± 0.07	203.70 ± 0.10
28	Jihua 9814	1.69 ± 0.07	0.48 ± 0.06	4.63 ± 0.07	108.62 ± 0.12	190.04 ± 0.05
29	Yuhua 15	2.33 ± 0.01	0.23 ± 0.00	3.59 ± 0.01	107.35 ± 0.04	217.14 ± 0.09
30	Yuhua 9326	2.28 ± 0.23	0.36 ± 0.01	4.04 ± 0.18	116.15 ± 0.03	179.49 ± 0.12
31	Yuhua 9327	1.61 ± 0.01	3.02 ± 0.01	4.31 ± 0.01	98.69 ± 0.08	203.20 ± 0.21
32	Kainong 30	3.43 ± 0.04	0.43 ± 0.00	4.49 ± 0.42	107.08 ± 0.05	188.68 ± 0.00
33	Kainong 37	3.20 ± 0.00	0.56 ± 0.00	4.49 ± 0.42	113.40 ± 0.12	193.60 ± 0.01
34	Yuanza 9102	4.95 ± 0.06	0.24 ± 0.00	3.70 ± 0.03	103.26 ± 0.06	186.93 ± 0.00
35	Heyou 11	0.31 ± 0.00	0.22 ± 0.00	4.31 ± 0.01		
36	Guihua 771	0.50 ± 0.02	0.36 ± 0.09	4.19 ± 0.03		
37	Yueyou 86	0.50 ± 0.004	0.37 ± 0. 03	4.59 ± 0.06		
38	Shanyou 250	0.52 ± 0.11	0.59 ± 0.18	5.43 ± 0.01		
39	Zhanhua 82	0.50 ± 0.008	0.22 ± 0.00	4.16 ± 0.07		
40	Pearl Red	0.48 ± 0.04	1.98 ± 0.00	5.12 ± 0.04		
41	Longhua 243	0.52 ± 0.03	0.34 ± 0.12	5.63 ± 0.09		
42	Yueyou 14	0.46 ± 0.11	0.81 ± 0.00	4.63 ± 0.04		
43	Minhua 9	0.45 ± 0.00	0.62 ± 0.00	5.02 ± 0.04		
44	Yueyou 45	0.51 ± 0.07	0.53 ± 0.09	4.79 ± 0.21		
45	Yueyou 40	0.50 ± 0.006	0.57 ± 0.09	4.58 ± 0.04		
	Average value	2.09	0.59	4.53	98.96	182.37
	Maximum value	4.95	2.57	5.76	116.14	217.13
	Minimum value	0.31	0.22	3.59	88.13	148.47
	Variation coefficient %	56.04	96.78	12.04	6.90	6.42

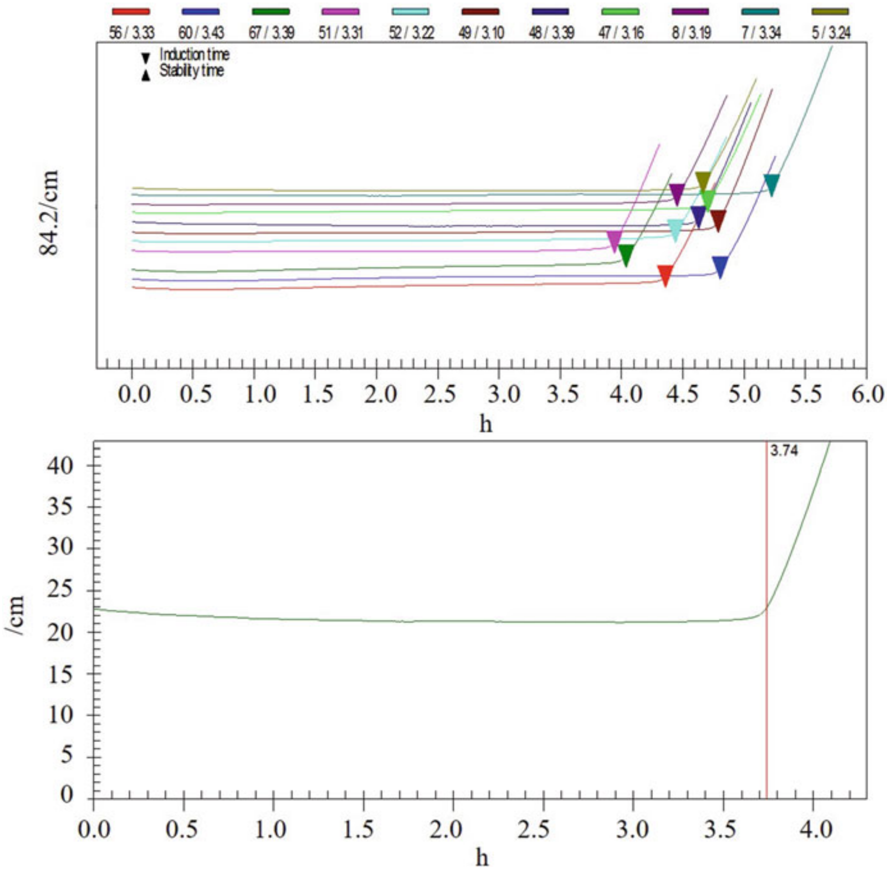

Fig. 3.2 Oxidation induction curve of peanut oil at 120 °C

correlation analysis. The results are shown in Table 3.10. It can be seen that except that the correlation coefficient between yellow and red was 0.493, and the correlation coefficient between saponification value and iodine value was 0.477, the correction coefficient between other indicators was small, indicating that the relationship between indicators was small, so it could be considered that the indicators were basically independent of each other, and they could be used as independent indicators to evaluate peanut oil.

Table 3.10 Correlation analysis between the quality indicators of peanut oil

	Red	Yellow	Water and volatile matter	Unsaponifiable matter	Induction time	Peroxide value	Acid value	Iodine value	Saponification value
Red	1.000								
Yellow	0.493**	1.000							
Water and volatile matter	0.154	−0.024	1.000						
Unsaponifiable matter	−0.229	−0.336	0.076	1.000					
Induction time	−0.066	−0.245	−0.137	0.105	1.000				
Peroxide value	−0.096	−0.034	0.346*	−0.121	−0.186	1.000			
Acid value	−0.049	−0.003	0.341*	0.065	0.070	0.071	1.000		
Iodine value	−0.184	−0.228	−0.119	0.386*	−0.123	−0.239	−0.109	1.000	
Saponification value	−0.014	−0.012	−0.13	0.022	−0.136	−0.383*	0.300	0.477**	1.000

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Note: (*) $P < 0.05$, (**) $P < 0.01$ showed that there was a significant or very significant difference between the data, respectively

Table 3.11 Sensory evaluation analysis of 26 varieties of peanut butter

Sample No	Average value	Standard deviation	Variation amplitude	Variation coefficient %
Color (9 scores)	6.74	1.07	8.40–4.29	15.84
Aroma (9 scores)	6.88	0.67	8.20–5.80	9.83
Texture state (9 scores)	6.83	0.36	7.40–6.00	5.47
Taste (9 scores)	6.79	0.58	7.80–5.29	8.66
Spreading (9 scores)	7.23	0.43	8.00–6.29	6.00
Overall acceptability (9 scores)	7.07	0.69	8.20–5.57	9.92

3 Quality Characteristics of Peanut Butter

3.1 Edible Quality

There was a certain difference in the sensory quality of 26 varieties of peanut butter. The results showed (Table 3.11) that there were different degrees of variation in the color, aroma, and taste of peanut butter processed from different varieties of peanut. According to sensory evaluators, the peanut butter processed from Huayu 22 (Shandong) variety was the best; it was yellow brown and shiny and could cause appetite, with pure braked peanut aroma, good tissue state, uniform butter, delicate taste, excellent viscosity, and smooth spreading; the overall acceptability score of its sensory score was 8.2, followed by Luhua 17, osmanthus 17, P905, Fuhua 12, and so on. We determined the hardness and viscosity of different varieties of peanut butter using texture analyzer. The result showed that (Table 3.12) there was a large difference in the hardness and viscosity of different varieties of peanut butter, with change ranges of 75.26-233.16 and 27.33-195.44, respectively, and the variation coefficients were 41.03% and 59.31%. Among them, the variety with the largest difference in hardness and viscosity was Jihuatian 1 (Hebei), and the variety with the smallest difference was Guihua 22 (Guangxi). Some studies have shown that the taste of sensory score and spreading have a certain degree of correlation with the viscosity determined by texture analyzer. Among them, the viscoelasticity determined by the instrument is able to predict the taste of sensory score, namely, the viscosity at the first mouth, the sample with smooth taste has low hardness and viscosity in the instrument (Abegaz and Kerr 2006), which is consistent with the results of this study. We determined the color of different varieties of peanut butter using color difference meter. Its significant difference was small; the variation coefficients of L^*, C^*, and H were smaller than 10, indicating that the baking degree of different varieties of peanut was similar to each other. Riveros et al. (2010) reported that when the color of peanut butter (L^* value) was 50 ± 1, its color was good, which had a certain influence on product appearance and overall acceptability by consumers. There was a small difference between this experiment and its study, and the value of Silihong was closest to it.

Table 3.12 Analysis of texture and color of 26 varieties of peanut butter

Peanut butter	Average value	Standard deviation	Variation amplitude	Variation coefficient %
Hardness (g)	114.40	46.90	72.96–233.16	41.03
Viscosity (g)	73.16	43.16	72.96–233.16	59.31
*L**	57.36	2.81	51.36–61.99	4.98
*C**	29.25	2.34	23.79–35.50	8.74
H	80.38	3.21	72.11–86.24	4.11

Note: *L**: brightness (black =0°, white = 100°), *C**: saturation, *H*: chromaticity (0° = red, 90° = yellow)

3.2 Analysis of Physicochemical and Nutritional Quality

The nutritional contents of peanut butter play a vital role in the quality of the final product. The physicochemical and nutritional quality analysis of 26 varieties of peanut butter is shown in Table 3.13. It can be seen from the table that the average value of crude protein content in peanut butter was 23.64% and the average value of crude fat content was 47.76%; the difference between the crude protein and crude fat contents in peanut was small, indicating that the protein and fat content loss during the processing of peanut butter was small; the water content range is 0.55–1.05%, which met the peanut butter water content limit ($\leq$1.5 g) specified in agricultural industry standards; although the variation range of other components was not clearly defined, the difference was less than that in peanut. Navnitkumar and Chun (2002) analyzed the quality of seven varieties of peanut butter in India. The results showed that the difference in the fat and protein content of the butters processed from different varieties of peanut was small, and the research of Navnitkumar and Chun (2002) showed that during the process of making peanut butter, the change in its physicochemical and nutritional quality indicators was small. It can be seen that the physicochemical and nutritional quality loss was not significantly different during the process of making peanut into butter, and the difference in the physicochemical and nutritional quality among different peanut varieties was small. In peanut fatty acid composition, the component with the highest content was oleic acid and linoleic acid, and the research of Özcan and Seven (2003) showed that the difference in the content change of oleic acid and linoleic acid was small during the process of making peanut into butter; the research of Savage and Keenan (1994) and Lopez et al. (2001) showed that the ratio between oleic acid and linoleic acid (*O*/*L*) was an important indicator to measure the storability of peanut raw materials and their products, i.e., the higher the ratio was, the more stable the oil quality was; the physiological functions of oleic acid included lowering cholesterol, regulating blood lipids, and decreasing blood sugar (Wahrbur 2004); oleic acid was also known as "safe fatty acid," and its content is an important indicator to assess fat quality (Liu et al. 2010). Therefore, the quality of peanut butter was significantly

Table 3.13 Analysis of physicochemical and nutritional quality of 26 varieties of peanut butter

Peanut butter	Average value	Standard deviation	Variation amplitude	Variation coefficient %
Water %	0.78	0.13	0.55–1.05	17.11
Ash %	3.19	0.27	2.58–3.50	8.48
Protein %	23.64	2.36	19.53–28.01	10.14
Total sugar %	13.22	2.91	9.66–21.82	22.31
Fat %	47.76	3.19	42.13–53.30	6.76
Fiber %	7.39	2.81	2.94–12.25	38.14
Oleic acid mg/100 g	21.82	5.74	13.40–36.49	27.91
Linoleic acid mg/100 g	14.28	5.14	1.84–20.52	36.78
Grain size (μm)	46.37	8.81	24.05–68.90	19.27

influenced by oleic acid and linoleic acid. The content ranges of oleic acid and linoleic acid in the peanut varieties selected in this experiment were 13.40–36.49 and 1.84–20.52, respectively, and the variety with highest oleic acid content was P905, which showed that the oleic acid and linoleic acid contents in 26 varieties of peanut were significantly different, and this had a great impact on the quality of the prepared peanut butter. China's agricultural industry standard stipulates that the grain size of peanut butter should be greater than 100 meshes but not clearly specifies its range. The average grain size of peanuts processed from 26 varieties of peanut in this research was 46.37 μ, and there was a certain difference in the grain sizes of different varieties. Among them, the two varieties of peanut butter of Guihuahong 95 and Luhua 18 had a significant difference.

3.3 *Stability Analysis*

The peroxide value is usually used to measure the oxidation degree at the initial oxidation of fat. The lower the peroxide value is, the better the initial stability of peanut butter is, and the less the oxidative rancidity and other similar phenomena is. The initial stability of 26 varieties of peanut butter is shown in Fig. 3.3. The variation range of peroxide value was 0.004–0.259 g/100 g, the value of Fuhua 18 (Liaoning) was the highest, and the value of 13–2 (Henan) was the lowest, showing that the stability of 13–2 was the best and the stability of Fuhua 18 was the worst among the 26 varieties of peanut butter when they were fresh. According to China's agricultural industry standards, the peroxide value of peanut butter (NY/T 958-2006 peanut butter) should be lower than 0.25 g/100 g, so it can be seen that Fuhua 18 peanut butter had exceeded the range specified in national standard when it was fresh. Riveros et al. (2010) mainly measured the stability of high oleic acid

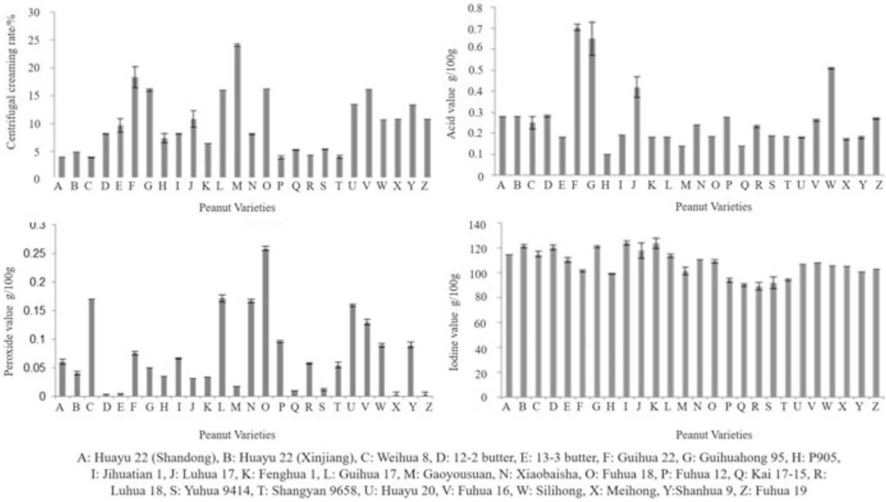

Fig. 3.3 Twenty-six analysis of initial stability of 26 varieties of peanut butter

and ordinary oleic acid using the change in peroxide value. The results showed that the stability of butter processed from high oleic acid peanut was good, and it was the variety with the lowest peroxide value content. Therefore, it can be seen from the figures that the initial oxidation stability of high oleic peanut butter is relatively good. The variation range of acid value was 0.09–0.705 g [KOH]/100 g, and the variety with the lowest acid value was P905 (Shandong). The greater the acid value was, the greater the degree of oxidative deterioration was, showing that the initial acid values of different varieties of peanut butter were significantly different. The variation range of iodine value was 99.22–123.997 g/100 g, and the vibration coefficient of iodine value was 70.15%, showing that the difference in iodine value was large among different varieties. The results obtained by Özcan and Seven (2003) after researching the iodine value of different varieties of peanut butter were consistent with the research results of this experiment. The variation range of centrifugal creaming rate was 4.0–18.38%, and the variation coefficient was 50.00%, showing that the difference in centrifugal creaming rate among different varieties was large. The lower the centrifugal creaming rate was, the smaller the degree of fat separation of peanut butter, and the better the stability effect was. Li et al. (2013) and Totlani (2002) found that the fat separation degree of peanut butter was good when the centrifugal creaming rate was low. Hinds et al. (1994) showed that the largest value of fat separation degree of fresh peanut butter was 0.5 ml within 24 h of storage according to the regulations of US Department of Agriculture. According to the variation coefficients (93.64%, 58.56%, and 50.00%) of peroxide value, acid value, and centrifugal creaming rate, the initial stabilities of butters processed from different varieties were significantly different.

Table 3.14 Analysis of quality correlation of 19 indicators of 26 varieties of peanut butter

	Protein	Water	Ash	Fiber	Total sugar	Oleic acid	Linoleic acid	Hardness	Viscosity	*L**	*C**	*H*	POV	AV	IV	Eccentricity	Receptiveness	Grain size
Fat	−0.227	−0.092	0.014	−0.069	−0.145	0.150	−0.075	−0.436*	−0.428*	0.280	0.080	0.112	−0.460*	0.116	−0.380	−0.115	0.020	−0.321
Protein	1	0.027	−0.068	−0.349	−0.602**	0.073	0.072	0.071	−0.142	−0.182	0.255	−0.249	0.226	0.233	−0.209	0.578**	−0.165	0.023
Water		1	−0.105	0.226	0.096	−0.155	0.002	0.099	0.073	−0.079	0.081	−0.070	0.169	−0.072	0.191	−0.024	−0.060	−0.149
Ash			1	0.080	−0.124	0.241	−0.107	−0.081	0.059	−0.215	0.275	−0.166	0.242	−0.266	−0.387	−0.080	0.122	−0.156
Fiber				1	0.191	−0.333	0.273	0.077	0.191	0.006	−0.008	−0.025	−0.030	−0.168	0.274	−0.250	0.239	0.002
Total sugar					1	−0.193	−0.327	0.422*	0.494*	−0.066	−0.324	0.153	−0.170	−0.044	0.478*	−0.323	−0.173	0.163
Oleic acid						1	−0.667**	−0.442*	−0.356	0.050	0.056	0.080	−0.248	−0.545**	−0.537**	−0.040	0.236	−0.287
Linoleic acid							1	0.026	0.031	0.170	0.101	−0.070	0.235	0.326	−0.021	−0.075	0.039	0.211
Hardness								1	0.842**	−0.410*	0.054	−0.320	0.159	0.192	0.377	−0.020	−0.496**	0.296
Viscosity									1	−0.514**	0.255	−0.503**	0.134	−0.162	0.266	−0.151	−0.193	0.195
*L**										1	−0.709**	0.859**	−0.212	0.090	−0.287	−0.183	0.068	−0.187
*C**											1	−0.912**	0.084	−0.125	−0.168	0.224	0.134	0.195
H												1	−0.116	0.106	−0.042	−0.237	−0.005	−0.231
POV													1	−0.081	0.079	0.182	0.093	0.163
AV														1	0.214	0.269	−0.428*	0.189
IV															1	0.102	−0.281	0.413*
Eccentricity																1	−0.268	0.350
Receptiveness																	1	−0.368

Note: **represent highly significant correlation ($P < 0.01$); *represent significant correlation ($P < 0.05$)

3.4 Analysis of Quality Correlation of Peanut Butter

In the processing industry of peanut, edible quality, physicochemical and nutritional quality, and stability have always been the focus of attention. The results of correlation analysis are shown in Table 3.14: the hardness and viscosity of peanut butter were significantly positively correlated ($r = 0.842$ **), indicating that the viscosity of peanut butter increased with the increase of hardness, which was consistent with the research results of Navnitkumar and Chun (2002) and Abegaz (2003). L* value, C*, and value, H value were significantly correlated ($r = -0.709$ **, $r = 0.0.859$ **), indicating that the more bright the peanut was, the more brown yellow its color was and the lower its color angle saturation was. There was a significant negative correlation between oleic acid and linoleic acid ($r = -0.667$ *). It was found by Özcan and Seven (2003) that after making peanut into butter, the variation difference of oleic acid and linoleic acid content was small, O/L value was not changed, indicating that the higher the oleic acid content of peanut was, the lower the linoleic acid content of peanut was, which was consistent with the research results of Zhang (2012) and Shin et al. (2010)

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