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Physicochemical and sensory quality evaluation of dried noodles from Chinese market based on principal component analysis and cluster analysis

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Abstract
In order to explore the quality diversity of different dried noodle products in Chinese market and construct an evaluation model, this study investigated physicochemical and sensory properties of nine commercially dried noodles, after which principal component analysis (PCA) and cluster analysis were applied to investigate interrelations and differences of various noodle samples, and sensory parameters of noodles were evaluated in addition. Results of physicochemical parameters of each sample, including moisture content (64.08~70.20%), protein content (0.139~0.607 g/100 g), elongation (13.78~37.49%), tension (18.33~38.67 g), chewiness (32.2~50.2 times), firmness (0.247~0.663 N), L*(from 87.013~92.290), a* (-2.820~-0.503), and b*(11.837~25.713) were calculated through factor analysis, where 4 main components were extracted with a cumulative contribution rate of 94.048%, reflecting comprehensive quality of the dried noodles. Quality scores Y of nine dried noodles obtained through a series of operations based on PCA were compared with those of sensory evaluations, which presented an appreciable consistent trend and to some extent reflects the reliability and effectiveness of the experiment. Cluster analysis divided nine brands of noodle into four categories, with similar quality within each category. This study shows that using general physicochemical parameters analysis and PCA to establish a quality evaluation model can effectively reflect the quality of dry noodles, and has certain application and reference value.

Keywords: Cluster analysis, dried noodles, PCA, quality, sensory

Introduction

Noodle, a staple food in many cultures such as China, Japan, and South Korea, are a type of long, thin, and cylindrical pasta made from wheat flour, water, and sometimes eggs (Chen *et al*., 2020) [1]. They can be served in various forms, such as dried, fresh, or fried, and are commonly found in dishes ranging from stir-fries to soups. Noodles with wheat as the main ingredient are a highly nutritious food source, containing complex carbohydrates, protein, and fiber. They also provide essential vitamins and minerals, such as iron, zinc, and B vitamins (Jeong *et al*., 2008) [2]. Wheat noodles are typically categorized as either white salted noodles made with the addition of sodium chloride or yellow alkaline noodles made with the addition of different combinations of sodium chloride and alkaline salts (Siah and Quail, 2008) [3]. Besides, instant noodle is also considered as one of the predominant styles of noodles (Bui and Small, 2007) [4]. Beyond Asia, noodle consumption has seen growth in markets such as North America, Europe, and Australia, where they are often incorporated into fusion dishes or enjoyed as a standalone meal (Jayasena *et al*., 2008) [5]. The rise in popularity of plant-based diets has also led to an increase in demand for noodle dishes featuring alternative protein sources.

The global market for noodles is highly competitive, with numerous manufacturers and brands vying for market share. Although there are various kinds of noodles on the market, including those with different food fortification functions, health care functions, interesting shapes, and tastes, in the final analysis, good quality and meeting the needs of consumers are the key to evaluating whether noodles are worth spending (Zhao *et al*., 2011; Anggraeni and Saputra, 2018; Chen *et al*., 2023) [6-8].

Therefore, conducting in-depth research on the quality of noodles and summarizing the general characteristics of excellent noodles can help consumers quickly find products that meet their own needs in the noodle market with mixed quality, which also help research and development institutions develop noodles that are popular and of good quality among consumers.

There have been many studies on the quality of noodles. Impacts of ingredients, pH, storage humidity and cooking on folate content of 26 commercial noodle samples was studied by Bui and Small (2007) [4]. Shibata *et al*. (2011) [9] used Fluorescence Fingerprint and constructed a calibration model with high accuracy to predict the proportion of buckwheat flour in commercial noodles. Voisey and Larmond (1973) [10] applied the MSC Ottawa testing system in the Instron instrument to evaluate the firmness, elasticity, and fracture velocity of noodles and found that the average force used in the measurement is significantly correlated with all sensory evaluation indicators, especially chewiness. Appropriate Superheated steam treatment can increase brightness, improve gelatinization properties, enhance dough strength, improve wheat flour quality, reduce cooking loss of noodles, and increase hardness, chewiness and adhesion of noodles (Wang *et al*., 2021) [11]. Hatcher and Symons (2007) [12] found that there is a correlation between the color of noodles and the protein content of wheat grains.

Sensory evaluation occupies an irreplaceable position in the evaluation of noodle quality (Shi *et al*., 2002) [13]. In different countries' evaluation systems, there are significant differences in the sensory evaluation standards of noodles. The Japanese noodle evaluation criteria mainly include color, surface condition, firmness, stickiness, smoothness, and taste (Zhang *et al*., 2007) [14]. The standard of wheat flour noodle processing quality evaluation in China includes firmness, elasticity, smoothness, taste, surface condition, and color as sensory evaluation parameters (SAC, 2018) [15].

Although there are many studies on the quality characteristics of noodles, there is a lack of systematic research on the comprehensive evaluation of the physicochemical and sensory quality of commercially available noodles in China (Chen and Shen, 2023) [8]. Given the Chinese preference for noodles as a breakfast staple, it is crucial to select high-quality, nutritious options that can effectively provide individuals with energy and nutrients to enhance their productivity and mental clarity throughout the day (Ding, 2008) [16]. However, with the wide range of noodle types available on the market, it can be challenging for consumers to make informed decisions regarding their purchases. Therefore, the establishment of a rapid and efficient noodle quality evaluation system is of paramount importance. This system would facilitate the selection of noodles based on their nutritional content, overall quality, and other key factors, ultimately benefiting consumers and promoting healthier dietary habits, which will have a significant impact on public health and wellbeing. Therefore, this study selected samples of nine different brands of the same type of noodles from Chinese market. Through sensory evaluation of the color, chewiness, taste, and other aspects of the noodles under the same cooking time and conditions, the related quality of the noodles was determined by experimental research on the protein content, tensile strength, and color of the noodles, and then the sensory quality and physicochemical properties of the noodles were comprehensively evaluated and analyzed through principal component analysis and cluster analysis. The main influencing factors affecting the eating quality of noodles were studied, and an effective quality evaluation system for dried noodle products was constructed.

Due to the many factors involved in noodle quality, principal component analysis was used in this experiment to utilize the data of each index more effectively. It can process multiple data into a few comprehensive indicators, which can represent the original data to a greater extent with fewer indicators, and can minimize the loss of original data (Feng and Ma, 2004) [17]. Therefore, it can more fully utilize the obtained data and reflect the studied problem more comprehensively. This study can provide a theoretical basis for the comprehensive evaluation of noodle quality and sensory evaluation, and provide reference basis for judging the quality of dried noodle products, which has practical significance.

Materials and Methods

Materials and Instruments

The materials analyzed in this study were procured online, consisting of nine distinct samples of dried wheat noodles sourced from varying origins without the addition of any extraneous substances, with sample-specific details outlined in Table 1. Reagents and main apparatus are as follow:

Coomassie brilliant blue G-250, AR, Tianjin Kemiou Chemical Reagent Co., Ltd; 96% Bovine serum albumin, BR, Beijing Huanke Biotechnology Co., Ltd; 95% ethanol, phosphoric acid, NaCl, AR, Guangdong Guangshi Reagent Technology Co., Ltd.

High-speed disintegrator 800Y, Wuyi Haina Electrical Appliances Co., Ltd; Electric thermostatic drying oven SFG-02B.400, Hubei Hengfeng Medical Pharmaceutical Equipment Co., Ltd; CT3 Brookfield Texture Analyzer, Brookfield, USA; UV-Vis spectrophotometer, INESA Analytical Instrument Co., Ltd; Colorimeter LS173, Shenzhen Linshang Technology Co., Ltd; Ultrasonic Cleaner CR-060S, Shenzhen Chunlin Cleaning Equipment Co., Ltd; Refrigerated high-speed centrifugator H1650R, Hunan Xiang Yi Laboratory Instrument Development Co., Ltd; Analytical balance ATY124, Shimadzu Philippines Corporation.

Table 1: Information of nine dried wheat noodles samples

Sample	Place of production	Ingredients
A	Xiaogan, Hubei	Wheat flour, cornstarch, water, salt gardenia yellow, sodium alginate
B	Jianmen, Guangdong	Wheat flour, water, sodium polyacrylate, curcumin
C	Qinghuangdao, Hebei	Wheat flour, edible starch, water, salt, sodium polyacrylate, curcumin
D	Quanzhou, Fujian	Wheat flour, cornstarch, water, salt, sodium polyacrylate, curcumin
E	Foshan, Guangdong	Wheat flour, water, sodium polyacrylate, curcumin
F	Ji'an, Jiangxi	Wheat flour, water, salt, sodium polyacrylate, guar gum, curcumin
G	Ganzhou, Jiangxi	Wheat flour, water, salt, sodium hexametaphosphate, sodium alginate, gardenia yellow
H	Heze, Shandong	Wheat flour, drinking water, salt, sodium carbonate, guar gum, glycerol monostearate, gardenia yellow
I	Jieyang, Guangdong	Wheat flour, tapioca, salt, sodium glutamate, disodium 5'-ribonucleotide, guar gum, sodium alginate

Sample Preparation

Noodle powder: nine distinct brands of dried wheat noodles sourced from varying locations were designated for identification as samples A to I, with a portion of the samples ground to powder by a high-speed disintegrator for future use.

Cooked noodle: The other dried wheat noodle samples were cooked in boiling water for 5 minutes, removed and rinsed in cold water for 10 seconds, blotted dry with a kitchen paper towel, and then placed in a disposable plastic cup sealed with cling film for further experiments.

Sensory Evaluation

Sensory evaluation adhered to GB/T 35875-2018 (SAC, 2018) [15], primarily evaluating the nine samples on six aspects: firmness, elasticity, smoothness, taste, surface state, and color (as detailed in Table 2). Fifteen evaluators receiving specialized sensory evaluation training were selected to assess each sample, prohibiting communication or discussion among evaluators, and necessitating a mouth-rinse between each noodle sample evaluation (Huang *et al.*, 2020) [18].

Table 2: Standard for sensory evaluation of noodle

Indexes	Grading standards	Score
Color (15-points)	Bright white or bright yellow	12-15
	Too white or too yellow	8-11
	Brightness and grey.	0-7
Surface state (15-points)	Clear transparent and watery with flawless surface	12-15
	Relatively transparent and watery with little flaw	8-11
	Over-swelling or has obvious fracture	0-7
Firmness (15-points)	Neither too hard nor too soft	12-15
	Slightly soft or slightly hard	8-11
	Too soft or too hard	0-7
Elasticity (20-points)	Good elasticity	16-20
	Moderate elasticity	10-15
	Poor elasticity	0-9
Smoothness (15-points)	Smooth and silky	12-15
	Relatively smooth	8-11
	Rough	0-7
Taste and smell (20-points)	Good wheat-smelling and taste	16-20
	With little wheat-smelling and light taste	10-15
	Stink or not taste quite right	0-9

Determination of Physicochemical Properties

Moisture content

Referring to GB 5009.3-2016 (SAC, 2016) [19], the direct drying method was used to determine the moisture content. Accurately weighing 2 g (precise to 0.001 g) of the cooked noodle sample into a tared dish, it was then placed in a drying oven and dried for 4 h at 105 °C, removed, placed in a desiccator, cooled for 30 min, and then weighed. This process was repeated until a constant mass was achieved (i.e., the weight difference between the penultimate and last weighing was less than 2 mg).

Protein content

Coomassie Brilliant Blue method is characterized by fast and sensitive detection and is commonly used to detect the protein content of food such as grain and dairy products (Li *et al.*, 2000) [20]. Protein contents of the nine samples was measured based on the Bradford method according to Ji (2011) [21]. Briefly, 0.1 g of flour, obtained by grinding with a high-speed disintegrator, was placed in a centrifuge tube containing 1.5 mL of distilled water. The tube was then ultrasonicated for 10 min, centrifuged at 12,000 r/min for 10 min, and the supernatant was transferred to another centrifuge tube. The precipitate was extracted again with distilled water using the same procedure, and the supernatant was combined with the first extraction. The final volume was adjusted to 1 m. Then, 0.1 mL of the extract was mixed with 0.9 mL of distilled water and 5 mL of Coomassie Brilliant Blue staining solution, and the mixture was allowed to sit and stain for 3 min. The absorbance was measured at 595 nm. Additionally, six clean test tubes were prepared, and series of standard protein solution, distilled water, and Coomassie Brilliant Blue staining solution of different concentration gradients were added, mixed and allowed to stand for 3 min, and the absorbance was measured at 595 nm. The standard curve was prepared by plotting the mass concentration of the standard protein solution against absorbance. Finally, the protein mass concentration of the sample was calculated based on the measured absorbance, and the fitted equation from the standard curve.

Elongation and tension

To determine the elongation and tension, equal-length boiled samples were used, and their original length and the length at the moment of rupture under tensile force were measured using a CT3 Brookfield texture analyzer. The elongation ratio was calculated, and the maximum tension was recorded. The experiment was conducted three times in parallel to obtain the mean value.

Chewiness

Equal-weight prepared samples were placed in a disposable plastic cup sealed with cling film. Five evaluators were asked to chew the noodles until which were no longer in a noodle shape, and were able to be swallowed. The average times of chews was then recorded (Ye, 2018) [22].

Cutting force

To determine the cutting force, equally prepared samples were held at both ends and the cutting force was measured using a CT3 Brookfield texture analyzer. The experiment was conducted three times in parallel to obtain the mean value.

Color
By using a colorimeter, the *L**, *a**, and *b** values of nine powdered samples were measured under the same light source and position. The *L** value represents brightness, with larger values indicating brighter colors. A positive *a** value indicates a red color bias, whereas a negative *a** value indicates a green color bias. A positive *b** value indicates a yellow color bias, whereas a negative *b** value indicates a blue color bias. The experiment was conducted three times in parallel to obtain the mean value.

Data processing and analysis
Microsoft Excel and Origin Pro were used for data collation, summarization and graphics. The IBM SPSS Statistics 21 software was used for factor analysis of the physicochemical properties and sensory evaluation of the noodles to investigate the factors contributing to these properties and evaluation results. Additionally, cluster analysis was used to create a dendrogram (Huang *et al.*, 2020) [18]. Prior to principal component analysis and cluster analysis, the data were standardized. Standardization is the process of subtracting the mean of each variable and dividing it by its standard deviation, resulting in standardized data with a mean of 0 and a standard deviation of 1 (Wei *et al.*, 2018) [23]. Using the "Analyze- Descriptive Statistics - Descriptive" command on IBM SPSS Statistics 21, the raw data were standardized. The analysis of the factors including *L**, *a**, *b**, chewiness, tension, elongation, cutting force, moisture content, and protein content of the noodles yielded the characteristic values of each principal component and their corresponding contributions to variance. Principal components with eigenvalues greater than 1.0 were used as the basis to determine the number of principal components and the coefficient matrix (Feng, 2021) [24]. The expression of each principal component was obtained and used to calculate the comprehensive score and rank of the nine different types of noodles. The highest quality noodle was selected based on the comprehensive score.

Results and Discussions
Sensory Evaluation
In sensory evaluation, sample G had the highest score of 85.133, while sample H had the lowest score of 75.800 (Table 3). Descriptive quantitative analysis results show that different noodle samples exhibited different trends in various sensory profile indicators (Figure 1). Due to the inconsistent range of scores for different sensory indicators, this study uses the proportion of actual indicator scores to the total score of that indicator to represent the results. Sample C had the best color and surface state, while sample F was not attractive in the same aspects. Sample G had the best tastes, smoothness and proper texture, which also had preferable elasticity as well as sample A. By contrast, sample D and sample H performed unsatisfactory in the same aspects even though sample D was given high score in taste and smell.

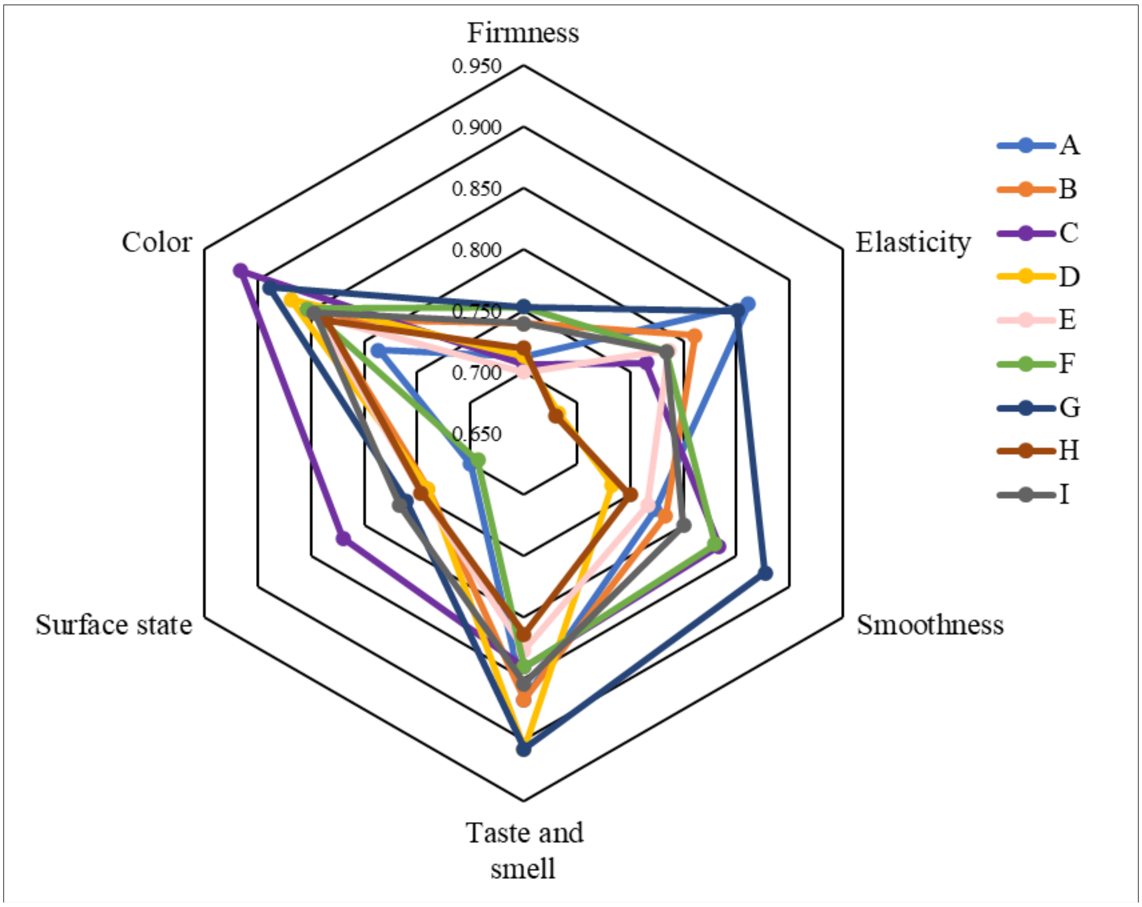


Fig 1: Sensory profile of nine noodle samples

Physicochemical Properties

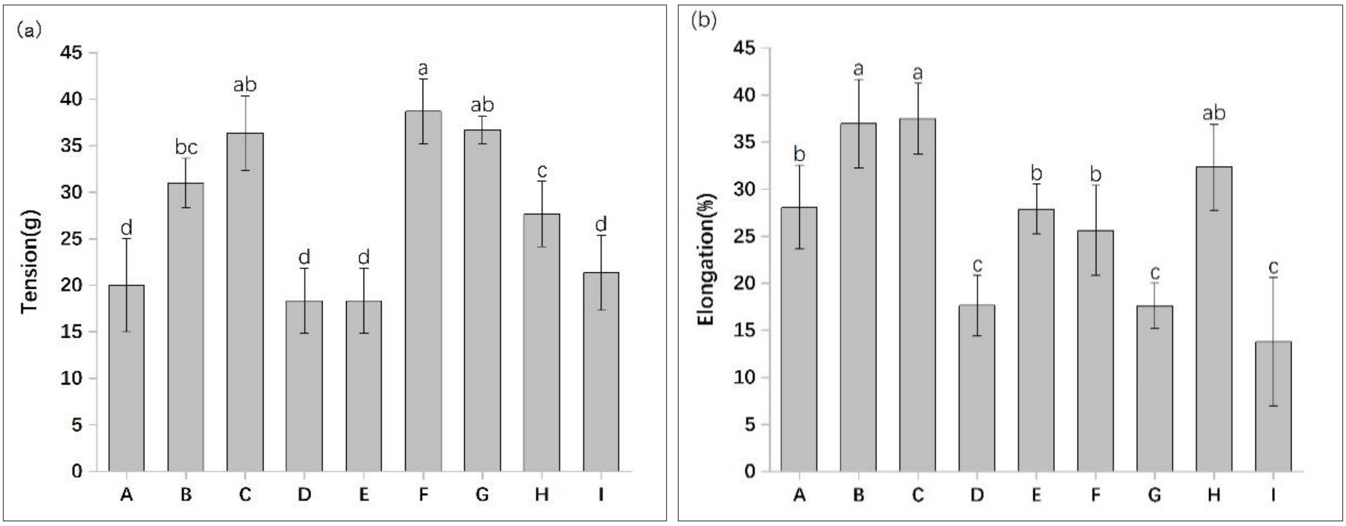
Table 3 shows the sensory evaluation and physicochemical properties of nine noodle samples. Noodles varied widely in color that sample I and B had the highest brightness value of 92.290 and 91.837 respectively, while sample H had the lowest value of 87.013. Sample E had the highest *b** value of 25.713, indicating a stronger yellow hue, while sample I had the lowest value of 11.837. Sample D had the highest *a** value of 2.82, indicating a stronger green hue compared to the other samples, while sample H had the lowest value of 0.503. Sample D had the highest moisture content of 70.197%, while sample G had the lowest at 64.083%. Protein contents in nine noodles showed significant differences that sample D had the lowest protein content at 0.139 g/100 g, while sample H had the highest of 0.607 g/100 g, which is 4.3 times of the sample with the lowest protein content. Besides, protein content of other samples ranged from 0.150 to 0.250 g/100 g.

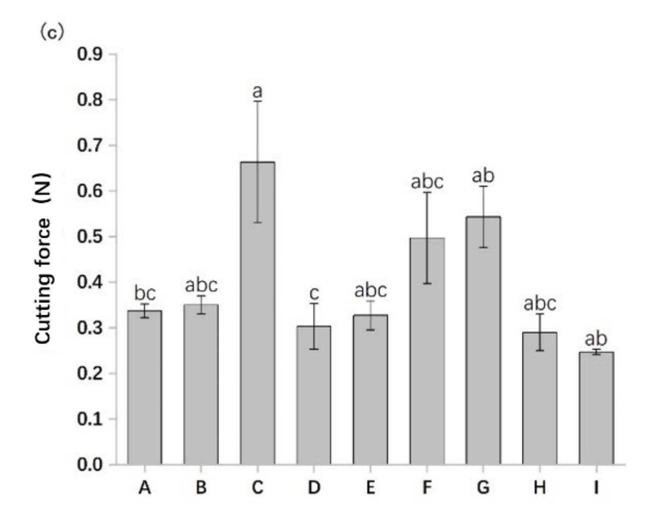
Table 3: Sensory evaluation and physicochemical properties of nine noodle samples

Sample	Sensory evaluation	L^*	a^*	b^*	Moisture content/%	Protein content (g/100 g)
A	79.067±7.469^{bc}	88.047±0.319^{e}	-2.197±0.116^{d}	19.230±0.524^{c}	69.213±3.025^{ab}	0.213±0.004^{d}
B	80.200±4.127^{abc}	91.437±0.023^{b}	-1.880±0.105^{c}	17.747±0.512^{d}	69.790±0.050^{ab}	0.249±0.004^{b}
C	82.733±8.224^{ab}	91.837±0.319^{ab}	-2.593±0.065^{e}	17.627±0.598^{d}	66.767±3.656^{abc}	0.155±0.008^{f}
D	76.867±4.373^{c}	89.037±0.690^{d}	-2.820±0.151^{f}	23.023±1.063^{b}	70.197±3.491^{a}	0.139±0.004^{g}
E	78.867±6.290^{bc}	88.500±0.353^{de}	-2.123±0.124^{d}	25.713±0.604^{a}	67.383±0.772^{abc}	0.225±0.007^{c}
F	80.467±5.668^{abc}	90.370±0.382^{c}	-2.183±0.199^{d}	22.313±0.645^{b}	66.083±0.320^{bc}	0.149±0.004^{f}
G	85.133±5.041^{a}	90.188±0.179^{c}	-2.193±0.777^{d}	17.760±0.308^{d}	64.083±0.356^{c}	0.180±0.004^{e}
H	75.800±8.654^{c}	87.013±0.170^{f}	-0.503±0.021^{a}	15.130±0.341^{e}	66.303±1.023^{abc}	0.607±0.006^{a}
I	80.333±4.701^{abc}	92.290±0.046^{a}	-0.883±0.038^{b}	11.837±0.294^{f}	67.473±0.250^{abc}	0.211±0.006^{d}

The means within row followed by different superscripts are significantly different at $p< 0.05$.

Figure 2 shows the physical properties of nine noodle samples, including tension, elongation, cutting force and chewiness. Sample F had the highest tensile strength of 38.67 g, while samples D and E had the lowest at 18.33 g. Sample C had the highest elongation rate of 37.49%, while sample I had the lowest at 13.8%, which was about one-third of the sample with the best ductility. Sample C had the highest cutting force of 0.663 N, while sample I had the lowest at 0.247 N. Sample C had the strongest chewiness, which needed averagely 56.6 times of chewing till it was totally homogenized by evaluators, while sample D had the weakest with 32.2 times of chewing. The quality of noodles is closely related to the raw materials and production process. In terms of tensile strength, sample C is flatter and wider than the other noodles, therefore they had higher tensile strength, chewiness, elasticity, and cutting force. On the other hand, sample D was relatively thin and not very long. When cooked for the same amount of time and cooled under the same conditions, they were softer and less chewy compared to the other noodles, resulting in lower tensile strength, chewiness, elasticity, and other aspects.





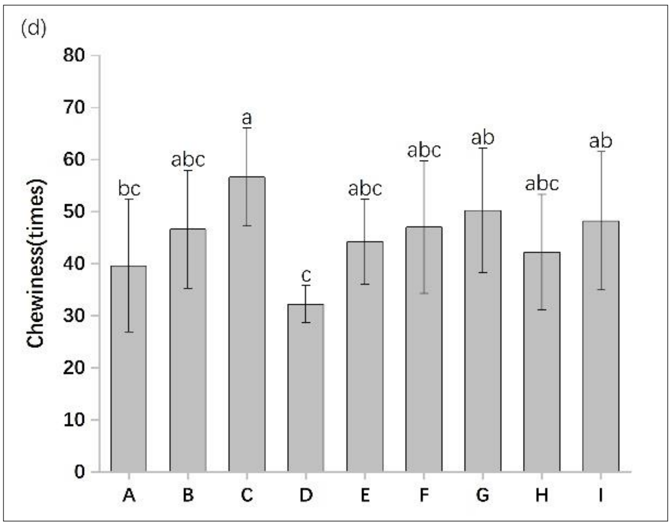


Fig 2: Physical properties of nine noodle samples: (a) Tension; (b) Elongation; (c) Cutting force; (d) Chewiness. * The means with different superscripts are significantly different at $p < 0.05$

Principal Component Analysis

Data from Table 3 were processed by IBM SPSS Statistics 21 software. Use the command "Analyze - Dimension Reduction - Factor Analysis" and select "Maximum Variance Method" for orthogonal rotation. Conduct a principal component analysis on each factor and extract factors with characteristic values greater than 1. The output of the factor analysis can be seen in Tables 4-5. In table 4, the cumulative variance contribution rate of PCA is up to 94.048%, which means the properties of dried noodles measured in this paper can explain about 94% of the variation in the quality of noodles, and has very good validity and representativeness according to Zhang and Dong (2013) [30].

Table 4: Principal component analysis of noodle qualities

Ingredient	Initial eigenvalue			Extracting sum of squares of loads		
	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	3.458	38.424	38.424	3.458	38.424	38.424
2	2.498	27.758	66.182	2.498	27.758	66.182
3	1.472	16.357	82.539	1.472	16.357	82.539
4	1.036	11.508	94.048	1.036	11.508	94.048
5	0.293	3.255	97.303			
6	0.202	2.242	99.544			

Table 5 is the principal component loading matrix for the nine physical and chemical properties of noodles, which mainly reflects the degree to which each factor affects the principal components (He *et al.*, 2021) [26] Table 6 is the rotated component matrix output from factor analysis, which mainly represents the main factors with correlation coefficients greater than 0.5 for each principal component. From the table, it can be seen that the first component includes the main indicators of *L**, *a**, and *b**, which can represent color-related factors of noodles; the second component includes main indicators such as tensile strength and elongation, which can represent the stretchability-related factors of noodles; the third component includes main indicators such as chewiness, cutting force, and moisture content, which can represent the chewiness-related factors of noodles; protein content becomes the fourth component, which can represent the nutritional factors of noodles.

Table 5: Principal component loading matrix for noodle qualities

Indexes	Component 1	Component 2	Component 3	Component 4
L^*	0.649	-0.091	-0.628	0.370
a^*	-0.243	0.941	-0.133	0.010
b^*	-0.173	-0.767	0.460	-0.239
Chewiness	0.900	0.273	-0.067	0.128
Tension	0.876	0.152	0.221	-0.069
Elongation	0.240	0.095	0.730	0.626
Cutting force	0.906	-0.237	0.257	-0.095
Moisture content	-0.605	-0.427	-0.109	0.648
Protein content	-0.355	0.819	0.428	0.014

Table 6: Principal Component Load Matrix after Rotation

Indexes	Component 1	Component 2	Component 3	Component 4
L^*	-0.908			
a^*	0.854			
b^*	0.813			
Chewiness	0.747		0.534	
Tension		0.973		
Elongation		-0.810		
Cutting force		0.789	-0.527	
Moisture content			0.953	
Protein content				0.984

From the eigenvalue of each principal component in Table 4 and the load of each index in Table 5, the functional expressions of four principal components can be calculated (Formula 1) to (Formula 4) (Huang *et al.*, 2020) [18]:

$$Y_1=0.349S_1-0.131S_2-0.093S_3+0.484S_4+0.471S_5+0.129S_6+0.487S_7-0.325S_8-0.191S_9 \quad (1)$$

$$Y_2=-0.058S_1+0.595S_2-0.485S_3+0.173S_4+0.096S_5+0.060S_6-0.150S_7-0.270S_8+0.518S_9 \quad (2)$$

$$Y_3=-0.518S_1-0.110S_2+0.379S_3-0.055S_4+0.182S_5+0.602S_6+0.212S_7-0.090S_8+0.353S_9 \quad (3)$$

$$Y_4=0.364S_1+0.010S_2-0.235S_3+0.126S_4-0.068S_5+0.615S_6-0.093S_7+0.637S_8+0.014S_9 \quad (4)$$

In the above formula: Where S_1 is color L^*, S_2 is color a^*, S_3 is color b*, S_4 is chewiness, S_5 is tension, S_6 is elongation, S_7 is cutting force, S_8 is moisture content, S_9 is protein content; S are dimensionless data.

Taking the variance contribution rate of each principal component as the weight, a comprehensive evaluation function is obtained. According to the comprehensive evaluation function, the comprehensive score (Y) of nine dried wheat noodle is calculated. The higher the comprehensive score, the better the quality of the noodle. As can be seen from Table 7, the quality of brand C (Y=1.278) is the best, followed by brand G (Y =0.557) and brand H (Y =0.541). Brand A, E, and I have relative poor-quality prediction results, where negative scores are given. Over all the noodle samples, Brand D(Y=-1.629) is significantly lower than other brands.

$$Y=0.384Y_1+0.278Y_2+0.164Y_3+0.115Y_4 \quad (5)$$

Table 7: Prediction and evaluation results of dried wheat noodle quality of different brands

Sample	Y_1	Y_2	Y_3	Y_4	Y	Ranking
A	-1.571	-0.669	0.371	0.282	-0.696	8
B	0.206	0.044	0.115	1.954	0.335	5
C	3.145	-0.443	0.518	0.936	1.278	1
D	-2.324	-2.265	-0.497	-0.226	-1.629	9
E	-1.132	-0.956	0.811	-0.476	-0.622	7
F	1.542	-0.655	0.400	-0.736	0.391	4
G	1.976	0.165	-0.385	-1.609	0.557	2
H	-1.475	3.233	1.484	-0.282	0.541	3
I	-0.366	1.545	-2.817	0.158	-0.154	6

While comparing the quality score (Y) in table.7 with the sensory evaluation score in Table 3, a highly similar pattern is found as shown in Figure. 3, where the noodle with a good sensory is also well qualify according to the result of PCA and vice versa. The highly positive correlation between sensory evaluation and quality predicted by model established in this paper indicates that using PCA to found the prediction model of dried wheat noodle quality is scientific and practicable, which is consistent with the actual situation and has certain reliability and validity.

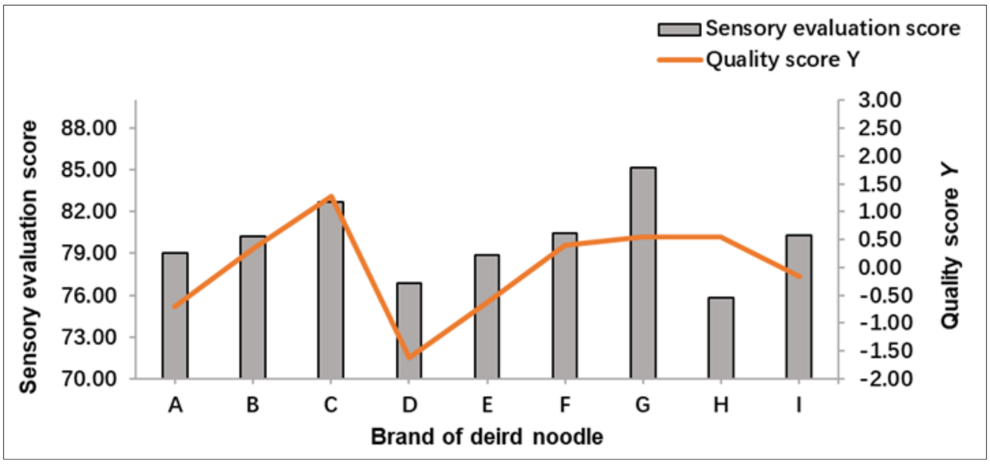


Fig 3: Comparison between sensory evaluation score and expected quality score *Y* of nine brands of dried wheat noodle

Cluster analysis

Cluster analysis is the process of dividing a dataset into categories based on reasonable criteria, ensuring similarity within the same class and maximizing differences between different classes (Eisen *et al.*, 1998) [27]. According to the results of principal component analysis, Pearson correlation is used as a metric to cluster the various physical and chemical properties of noodles, as shown in Figure 4.

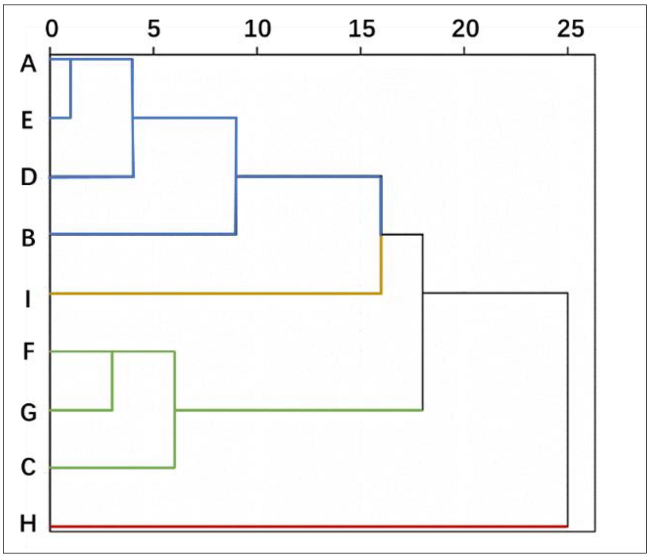


Fig 4: Cluster analysis tree diagram of different brands of dried wheat noodle

The dendrogram obtained from cluster analysis reveals that at a distance of 15, nine types of noodles can be classified into four groups, and noodles in the same group have similar overall quality. The first group consists of noodles A, E, D, and B, which rank near the bottom in terms of tensile strength, chewiness, and sensory evaluation. Their rankings are also relatively low in factor analysis and sensory evaluation. The second group consists of noodle I, which has no added coloring agents and therefore appears white, with the highest *L** value indicating maximum brightness. It also contains guar gum (Yu and Ngadi, 2010)[28], which enhances the noodle's elasticity and ranks third in chewiness. The third group includes noodles F, G, and C, which rank in the top three in terms of tensile strength, cutting force, and sensory evaluation. They also rank relatively high in chewiness and have good taste. Noodle H forms the fourth group, and is made with added sodium bicarbonate (Wang *et al.*, 2008) [29], which enhances its elasticity and extensibility, ranking third in extensibility.

Conclusions

This study investigated nine physical and chemical properties, including protein content, color, moisture content, chewiness, tensile strength, elongation, and cutting force of commercially available dried noodle products. Principal component analysis was used to extract four principal components that accounted for 94.048% of the total variation. Cluster analysis was then performed to classify the nine noodle varieties into four groups. The results of this study provide a certain reference value for consumers in selecting dried noodle products.

The data analysis results obtained in this study exhibited some similarity with the sensory evaluation results. However, they were not identical. This discrepancy is partly due to the incomplete selection of textural indicators and the simplification of some methods due to experimental constraints, leading to certain deviations in the results. Future studies can use more textural indicators, more optimal and accurate methods, and more complete sensory evaluation standards to obtain more abundant and accurate experimental data, thus obtaining more scientific and reference able experimental results.

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