Analysis of the Eating Quality of Rabbit Meat Products Based on Sensomics Methods

Ban Qian[1, 3, *], Huang Daomei[2], Zuo Xiangbing[3]

[1]Guizhou Sunshine Grass Industry Technology Company Limited, Dushan 558207, China
[2]Integrated Agricultural Development Research Institute, Guizhou Academy of Agricultural Sciences, Guiyang 550006, China
[3]Institute of Prataculture, Guizhou Academy of Agricultural Sciences, Guiyang 550006, China

Abstract: In this paper, the edible quality of five commercial rabbit meat products was explored by using sensomics method, and the purpose of this experiment was to provide a reference for the precise analysis of rabbit meat processing and the quality of rabbit meat products. The results showed that the five products performed differently, and Y4 had the best comprehensive performance among the five commercial rabbit meat products. There was no significant difference in morphology among the five products. In terms of color, the sensory combined with color difference analysis showed that products Y4 and D2 were significantly better than the other three. In terms of odor, the sensory combined with electronic nose technology analysis showed that product D2 was significantly worse than the other four. The sensory, moisture content, and texture analysis all indicated that product Y4 had significant advantages in taste, while products T1 and D2 were poor. In terms of chewiness, products Q5, Y4, and T1 were significantly better than products H3 and D2. The research results showed that the traditional sensory evaluation method can be integrated with detection technologies such as electronic nose, texture, and color difference, providing technical support for the in - depth research and development and quality control of rabbit meat products.

Keywords: Rabbit Meat; Sensory Evaluation; Textural Properties; Electronic Nose Technology

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1 Introduction

In China, the rabbit industry has always been an important driver of rural revitalization due to its suitability for small-scale family farming, rapid reproduction, easy-to-master breeding techniques, and quick return on investment [20]. Rabbit meat, with its advantages of low fat, low cholesterol, low energy, high protein, high mineral content, high digestibility, and tender texture, not only meets the health-conscious dietary needs of modern consumers but also satisfies the special dietary requirements of people with high blood pressure, high cholesterol, and high blood sugar [2]. The domestic market demand for rabbit meat has been increasing year by year [8]. With the upgrading of consumption, consumer demand has shifted from traditional rabbit meat consumption to diversified rabbit meat products and deep-processed rabbit meat products [3, 6, 13].

As of 2020, Asian rabbit meat production reached 634,024.78 tonnes, mainly concentrated in China and North Korea, while European rabbit meat production reached 153,150.08 tonnes, mainly concentrated in the

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*Corresponding author: Ban Qian, 874394436@qq.com

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European Union and Russia Federation [14]. Rabbit meat production and processing were mainly concentrated in the southwestern regions of Sichuan, Chongqing, Guizhou, as well as Henan and Shandong of China [20]. Frozen and fresh rabbit meat account for more than 90% of consumption, while deep-processed products account for less than 10%, mainly including marinated, braised, and cured rabbit meat products, as well as leisure products such as diced meat, shredded meat, and jerky. The current research on rabbit meat processing in China and abroad mainly focuses on flavor research and processing techniques. According to *Xie* research on rabbit meat, hexanoic acid, hexanal, octanal, nonanal, (*E*, *E*)-2,4-decadienal and 1-octen-3-ol were the key odor components of rabbit meat [17]. Rabbit meat with low temperature can inhibit the attenuation of volatile flavor substances and prolong the retention time of the flavor of the dish [18]. Many scholars have used different detection technologies to explore the flavor substances of rabbit meat and its products [16, 19]. In addition, many researches have been explored various processing techniques for rabbit meat products, all of which have achieved certain research results [4, 9, 10, 21]. One of those research indicated it was feasible to ues corn germ oil instead of animal fat to prepare western-style rabbit meat ham rich in corn germ oil, made with 8.0% corn germ oil, 68% rabbit meat, 15% ice water, and 5.0% cassava modified starch.

This experiment selected five commercially available rabbit meat products as research subjects and used traditional sensory evaluation combined with color difference, texture characteristics, and electronic nose odor analysis to explore the edible quality of different rabbit meat products based on sensomics methods. The aim is to provide methods and technical support for the in-depth research and development and quality control of rabbit meat products.

2 Materials and Methods

2.1 Materials

Five rabbit meat products sample sources were selected through online and offline sales platforms that were popular among consumers, and products from the same production batch were purchased.

2.2 Instruments and Equipment

TMS-PRO texture analyzer (with P50 disc probe), from Food Technology Corporation Company, USA. SN-DH5-16A halogen moisture content analyzer, from Shanghai Shangpu Instrument Equipment Co., Ltd.. PEN3 portable electronic nose, from AIRSENSE Analytics Company, Germany. FA2004 analytical balance, from Shanghai Precision Scientific Instrument Co., Ltd.. 3nh NH310 colorimeter, from Guangdong SanEnShi Intelligent Technology Co., Ltd.

2.3 Methods

2.3.1 Sensory Evaluation

Ten students and teachers majoring in food science in the food processing department laboratory of Integrated Agricultural Development Research Institute laboratory were selected as evaluators. A weighted method was used to evaluate visual, olfactory, taste, and texture aspects [1, 7]. The specific evaluation criteria and score weights are shown in Table 1.

Table 1 The Evaluation Criteria of Sensory Indexes

Indicator and Weight	**Evaluation Criteria**	**Score**
	Bright and evenly distributed meat color	5-6
Color (10%)	Bright but unevenly distributed meat color	3-4
	Dull and unevenly distributed meat color	1-2
	High integrity and uniform size of meat pieces	5-6
Shape (10%)	Slightly damaged and relatively uniform size of meat pieces	3-4
	Severely damaged and non-uniform size of meat pieces	1-2
	Strong spicy and meaty aroma, no off-flavors	5-6
Odor (20%)	Moderate spicy and meaty aroma, slight off-flavors	3-4
	No aroma, obvious off-flavors	1-2
	Spicy and delicious, moderate saltiness, no off-flavors	5-6
Taste (30%)	Mild spiciness, moderate saltiness, slight off-flavors	3-4
	Very mild spiciness, too salty or too bland, with off-flavors	1-2

Indicator and Weight	Evaluation Criteria	Score
	Tight and non-loose texture, good elasticity, tender and refreshing	5-6
Chewiness (25%)	Relatively tight texture, good elasticity, relatively tender and refreshing	3-4
	Loose texture, poor elasticity, less tender	1-2

2.3.2 Moisture Content Determination

The products were spread on a filter tray, excess fat and seasonings were removed, and the five rabbit meat dices were processed into small particles of similar size and shape. A 5.00g sample was spread on a test tray for moisture determination, with a drying temperature of 105℃. Each sample was repeated three times, and the average value was taken.

2.3.3 Color Difference Measurement

Rabbit meat dices of the same size were selected, and the colorimeter was calibrated before measurement. Each sample was measured five times in parallel, and the average value was taken.

2.3.4 Texture Characteristics Measurement

Rabbit meat dices of uniform size were selected and trimmed into 2cm cubes for testing. Test conditions: sensor range 980N, P50 probe, probe return height to sample surface 20mm, deformation percentage 30%, detection speed 30mm/min, initial force 1.5N. Each sample was measured 10 times in parallel, and the average value was taken after removing outliers [11].

2.3.5 Odor Analysis

The products were processed into small particles of suitable and uniform size. A 5.00g sample was placed in a 50ml headspace bottle, immediately sealed, and equilibrated at room temperature for 20 minutes before electronic nose testing [12]. Each sample was tested five times in parallel. Test conditions: sampling interval 1s, cleaning time 50s, zeroing time 5s, testing time 80s, carrier gas flow rate 400mL/min, sample flow rate 400mL/min [5, 15].

2.3.6 Data Analysis

All data were statistically analyzed and subjected to variance analysis using SPSS21 software, with $p<0.05$ indicating significant differences. All charts were drawn using Origin 2024 software.

3 Results and Analysis

3.1 Sensory Evaluation Results of Five Rabbit Meat Products

Table 2 showed the sensory evaluation results of the five rabbit meat products, and the sensory scores for color, shape, odor, taste, and chewiness were plotted as a radar chart, as shown in Figure 1.

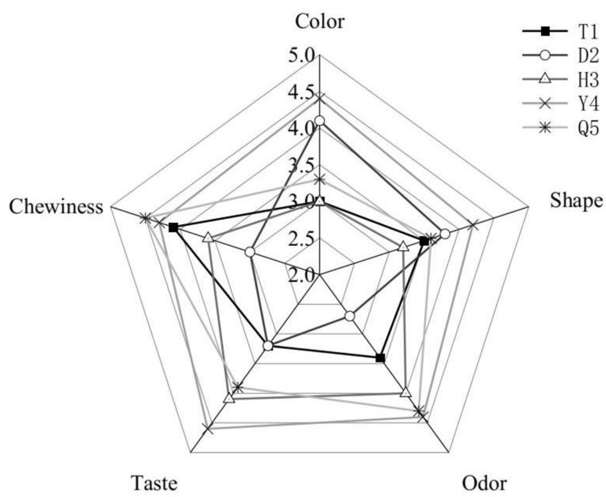

Figure 1 Radar chart of sensory evaluation

From Figure 1, it can be seen that the five rabbit meat products performed differently in terms of color, shape, odor, taste, and chewiness. Product Y4 scored the highest and was relatively balanced in all aspects. Product T1 performed well in chewiness but was average in the other four aspects, especially in color, where it scored the lowest among the five products. Product D2 performed moderately in color and shape but poorly in odor, taste, and chewiness. Product H3 performed well in odor, taste, and chewiness but was lacking in color and shape. Product Q5 had the best chewiness among the five products and performed well in taste and odor but was below average in color and shape.

From Table 2, it can be seen that after calculating the total score based on the weight ratio, the sensory results of the five rabbit meat products were Y4 > Q5 > H3 > T1 >

D2. Product Y4 had the best sensory result, with a total score of 4.43 ± 0.34a, significantly different from the other four groups ($p<0.05$), and it was the best in color, shape, odor, taste, and chewiness, with significant differences. The total sensory scores of products Q5 and H3 were 4.04 ± 0.39b and 4.04 ± 0.39b, respectively, with no significant difference between them ($p<0.05$). The total sensory scores of products T1 and D2 were poor, at 3.48 ± 0.39bc and 3.20 ± 0.31c, respectively, with no significant difference between them ($p<0.05$).

Table 2 Results of sensory evaluation

Sample	Color	Shape	Odor	Taste	Chewiness	Total Score
T1	0.30±0.07b	0.35±0.13ab	0.68±0.10b	1.12±0.05c	1.03±0.14a	3.48±0.39bc
D2	0.41±0.06a	0.38±0.10ab	0.54±0.13c	1.12±0.22c	0.75±0.17b	3.20±0.31c
H3	0.30±0.09b	0.32±0.08b	0.80±0.13ab	1.44±0.26b	0.90±0.13b	3.76±0.40b
Y4	0.44±0.05a	0.42±0.04a	0.88±0.14a	1.61±0.18a	1.08±0.12a	4.43±0.34a
Q5	0.33±0.05b	0.36±0.05ab	0.86±0.19a	1.37±0.20b	1.13±0.13a	4.04±0.39b

Note: Different lowercase letters in the same column indicate significant differences ($p<0.05$).

3.2 Moisture Content Determination Results of Five Spicy Rabbit Meat Products

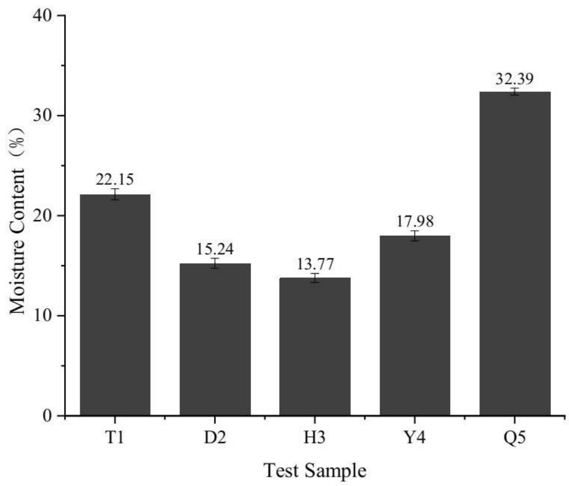

Figure 2 Test results of moisture content

Moisture content was one of the important indicators for food testing, significantly affecting the final product quality and yield. For meat processing products, moisture content also affects hardness and chewiness. The moisture content test results of the five rabbit meat products were shown in Figure 2. The moisture content of the five rabbit meat products varied significantly, with T1, D2, H3, Y4, and Q5 having moisture contents of 22.15%, 15.24%, 13.77%, 17.98%, and 32.39%, respectively. Product Q5 had the highest moisture content, followed by products T1 and Y4. Product H3 had the lowest moisture content, and product D2 had the second-lowest moisture content. This indicated that product H3 had the highest hardness and the worst chewiness, while product Q5 had the best chewiness, and products T1 and Y4 had relatively good chewiness. This is consistent with the sensory evaluation results for hardness and chewiness, indicating that moisture content can well reflect the hardness and chewiness of the products.

3.3 Color Difference Measurement Results of Five Rabbit Meat Products

Color played an important role in the sensory evaluation of meat products, directly affecting consumers' acceptance of the product's appearance and was one of the key factors influencing consumer purchasing decisions. Figure 3 showed the chromatic aberration values (L^*, a^*, b^*) of the five different rabbit meat products. L^* represents lightness, a^* represents the shift from yellow to blue, and b^* represents the shift from green to red. The higher the L^* value, the darker the color; the higher the a^* value, the more the color shifted to blue; and the higher the b^* value, the more the color shifted to red.

From Figure 3, it can be seen that the L^* values of the five products were T1 (34.14) > D2 (26.46) > Y4 (25.11) > Q5 (23.30) > H3 (21.53), indicating differences in brightness among the products. Product T1 had the brightest color, significantly different from the other groups ($p<0.05$). Products D2 and Y4 had relatively bright colors, with no significant difference between them ($p<0.05$). Products H3 and Q5 had slightly darker colors, with no significant difference between them ($p<0.05$). Comparing the a^* values of the products, products T1, D2, and Y4 had relatively higher a^* values, with no significant differences between them ($p<0.05$). Products H3 and Q5 had slightly lower a^* values, with no significant difference between them ($P < 0.05$), indicating that the a* values of the five products did not differ significantly and had little impact on color. Analyzing the b* values of the five products, product T1 had the highest b* value at 20.68, followed by product D2 (16.63), significantly different from the other three groups ($p<0.05$). The b* values of products Y4 and Q5 were 12.60 and 11.67, respectively, with no significant difference, while product H3 had the lowest b* value at 10.40. Comprehensive analysis showed that products D2 and Y4 had slightly higher L* and b* values than products Q5 and H3, indicating better overall color, which is consistent with the sensory evaluation results for color. However, product T1 had the highest color difference values (L*, a*, b*), with L* and b* values significantly higher than the other four groups ($p<0.05$), but its sensory color evaluation score was relatively low, indicating that the high b* value made the color of product T1 too red, which did not meet consumers' optimal expectations for product color.

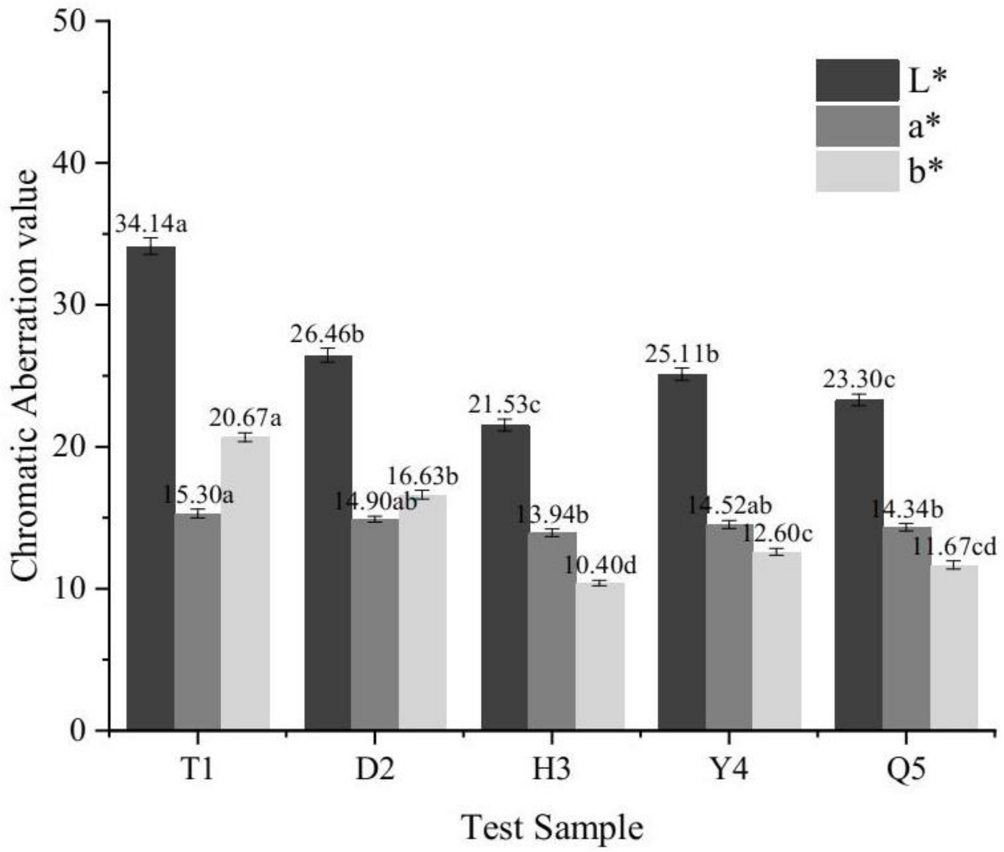

Figure 3 Chromatic aberration values of different rabbit meat products

3.4 Texture Characteristics Results of Five Rabbit Meat Products

Texture parameters directly reflected the sensory taste and chewiness of products. Table 3 showed the texture measurement results of the five rabbit meat products. From Table 3, it can be seen that product H3 had the highest hardness and chewiness values, significantly different from the other groups ($p<0.05$), and it scored the lowest in sensory chewiness evaluation. Product D2 had the second-highest hardness and chewiness, consistent with its sensory evaluation score. Products T1, Y4, and Q5 had no significant differences in hardness and chewiness ($p<0.05$), consistent with their sensory chewiness evaluation results. In terms of elasticity, product Y4 was higher than products T1 and Q5, giving it a slightly better taste. The results for adhesiveness were consistent with hardness and chewiness. Considering hardness, elasticity, chewiness, and adhesiveness, product Y4 had the best texture results, consistent with the sensory evaluation results.

Table 3 Texture Measurement Results of Different Products

Product	Hardness	Elasticity	Adhesiveness	Chewiness
T1	18.63±1.29c	1.24±0.28bc	8.77±0.91b	10.80±2.26c
D2	31.17±2.22b	1.78±0.18b	15.93±2.57a	28.00±3.18b
H3	38.83±2.37a	2.43±0.69a	19.17±1.77a	46.00±10.28a
Y4	18.80±6.86c	1.52±0.23b	8.63±3.37b	12.67±2.89c
Q5	20.53±2.91c	0.72±0.16c	10.63±1.89b	7.67±2.10c

Note: Different lowercase letters in the same column indicate significant differences ($p<0.05$).

3.5 Odor Measurement Results of Five Rabbit Meat Products

Table 4 showed the 10 sensors of the electronic nose and their response substances and performance descriptions. The radar chart of the electronic nose sensor response values for the five products was shown in Figure 4. From Figure 4, it can be seen that the response values of the five rabbit meat products on the W1W, W5S, and W2S sensors varied significantly, while the response values on the other sensors were basically overlapping, indicating significant differences in the content of sulfides, nitrogen oxides, alcohols, and aldehydes and ketones among the five products.

Table 4 Types and performance of electronic nose sensors

Array Number	Sensor Name	Representative Substances	Performance Description
1	W1C	Aromatic	Aromatic components, benzene
2	W5S	Broadrange	High sensitivity, very sensitive to nitrogen oxides
3	W3C	Aromatic	Sensitive to aromatic components, ammonia
4	W6S	Hydrogen	Selective for hydrogen compounds
5	W5C	Arom-aliph	Short-chain alkanes, aromatic components
6	W1S	Broad-methane	Sensitive to methyl groups
7	W1W	Sulphur-organic	Sensitive to sulfides
8	W2S	Broad-alcohol	Sensitive to alcohols and aldehydes/ketones
9	W2W	Sulph-chlor	Aromatic components, sensitive to organic sulfides
10	W3S	Methane-aliph	Sensitive to long-chain alkanes

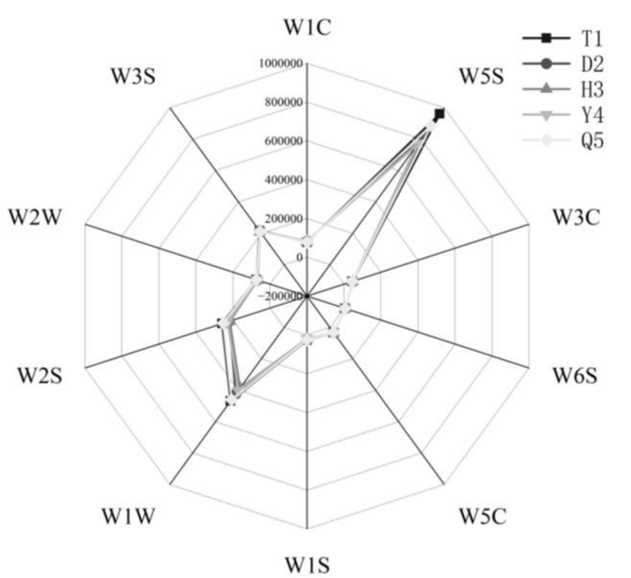

Figure 4 Electronic nose radar chart of different rabbit meat products

Further PCA and LDA analyses were conducted on the five rabbit meat products, and the results were shown in Figures 5 and 6. These analyses showed that electronic nose detection technology can effectively distinguish different rabbit meat products. In the PCA analysis, the contribution rates of PC1 and PC2 were 97.90% and 2.05%, respectively, with a total contribution rate of 99.95%, indicating that the analysis results covered the main information of the samples with high reliability. In the PCA analysis chart, product D2 was far from the other groups, indicating that its odor was significantly different from the others. From the LDA chart, it can be seen that the contribution rates of the first linear discriminant factor (LD1) and the second linear discriminant factor (LD2) were 98.21% and 0.90%, respectively, with a total contribution rate of 99.11%. Product D2 was far from the other groups, consistent with the PCA analysis, indicating that its odor was significantly different from the other four groups. From the PCA analysis, it can be seen that products T1 and H3 were close to each other, with some overlap, and products H3 and Y4, as well as products Y4 and Q5, also overlapped, indicating that their odors were similar with no significant differences, which was completely consistent with the sensory odor evaluation results.

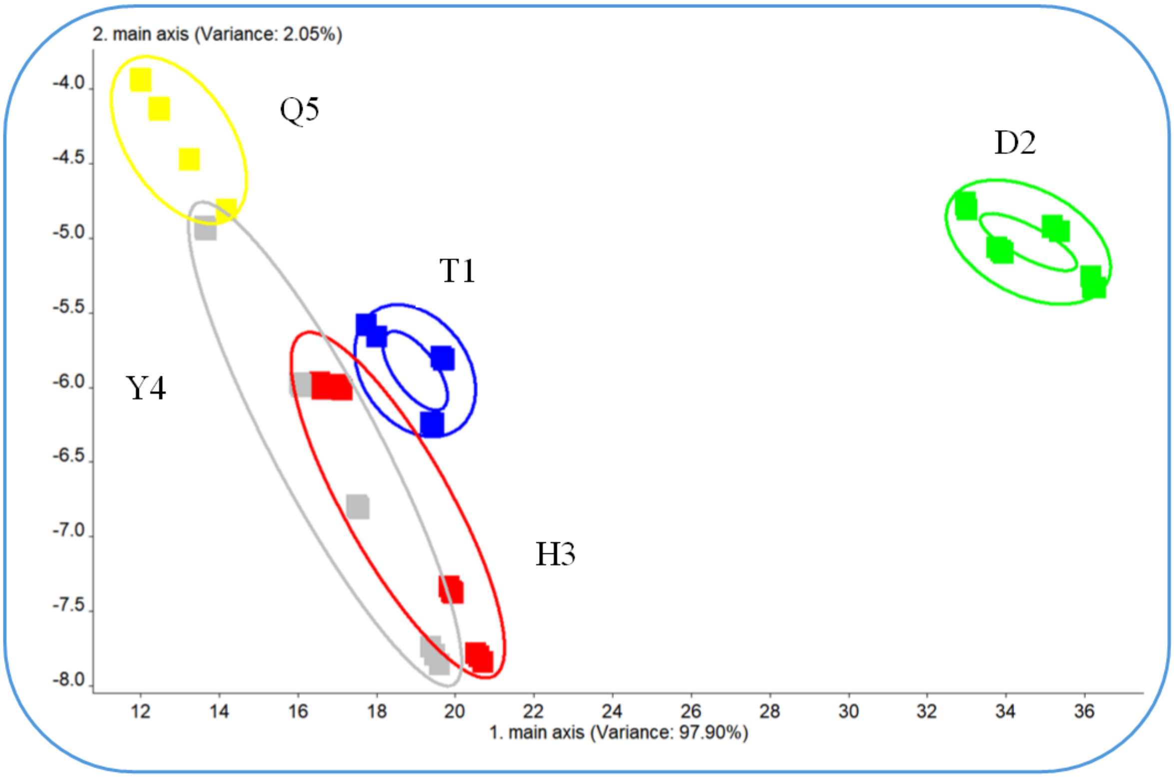

Figure 5 PCA analysis of electronic nose for different rabbit meat products

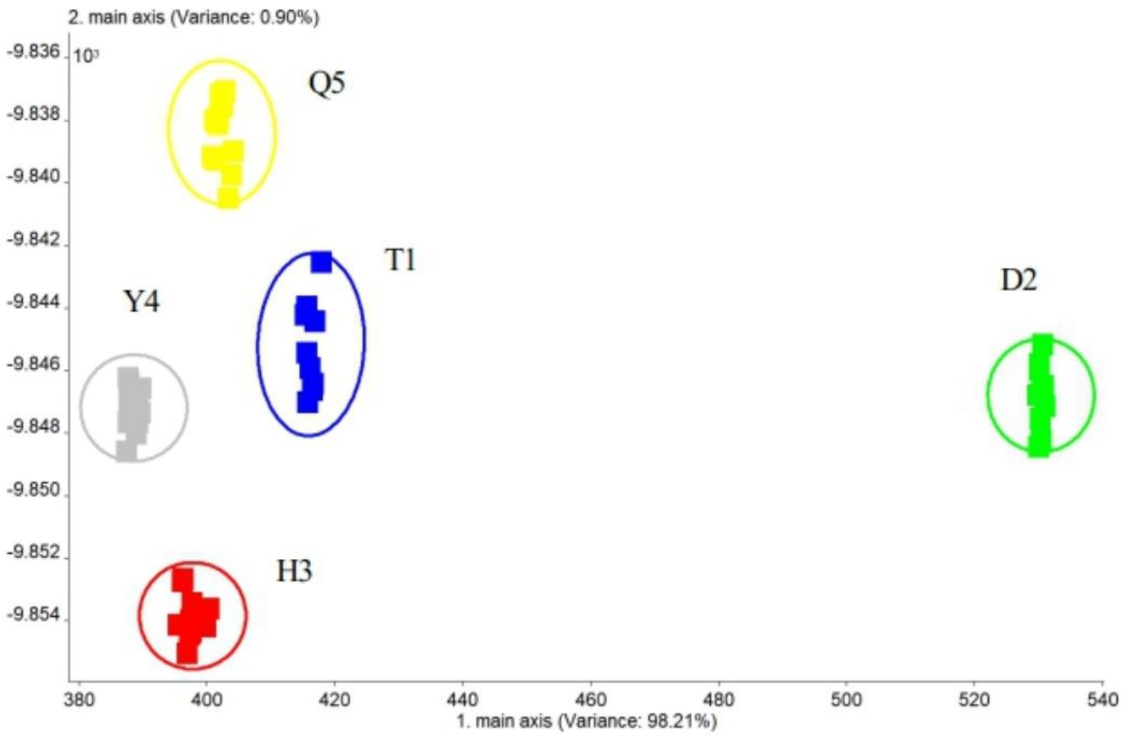

Figure 6 LDA analysis of electronic nose for different rabbit meat products

4 Conclusion

This study used sensomics technology, including sensory evaluation, moisture determination, texture analysis, color difference analysis, and electronic nose analysis, to investigate the edible quality of five commercial rabbit meat products. The sensory evaluation results showed that the five products performed differently, in terms of color, products Y4 and D2 were significantly better than the other three. In terms of shape, there was no significant difference among the five products, from the color difference results, products D2 and Y4 had better overall color, while product T1 had the highest brightness but its color was too red, consistent with the sensory evaluation results. In terms of odor, product D2 scored the lowest, significantly lower than the other four, and electronic nose analysis also showed that product D2's odor was significantly different from the others. In terms of taste, product Y4 had significant advantages, while products T1 and D2 were poor. In terms of chewiness, products Q5, Y4, and T1 were significantly better than products H3 and D2. The moisture content determination and texture analysis results showed that products D2 and H3 had relatively low moisture content, higher hardness, and poorer chewiness, while product Q5 had the highest moisture content and the best chewiness, consistent with the sensory results. Therefore, the combined sensomics technology evaluation showed that product Y4 was the best among the five commercial rabbit meat products. This study provides a basis for the development and precise analysis of the edible quality of rabbit meat products and is expected to provide a reference for the in-depth application of sensomics technology.

Disclosure Statement

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be a potential conflict of interest.

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