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Control of Post Fermentation Process and Quality Evaluation for Frying and Roasting Purposes of Dry-aging Beef

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Abstract: In this study, Simmental hybrid yellow beef was used as raw material and sensory quality of beef was taken as the research object. The effects of time, temperature and wind speed on the quality of Simmental hybrid yellow beef were considered, and the optimum ripening conditions were obtained through single factor experiment and orthogonal experiment. The flavor changes of fried beef under different dry aging conditions were studied by SPME-GC-MS and ATR-FTIR combined with traditional physicochemical analysis methods. The volatile components of beef in blank group (A), experimental group (B) and control group (C) were determined by SPME-GC-MS technology. The volatile components common to the three types of beef were screened out according to the relative content and OAV value for principal component analysis, and the comprehensive beef scoring equation was established to obtain the comprehensive scores of the three groups of beef. The research shows that: With the passage of ripening time, the pH value of beef showed an increasing trend, which may be due to the protein in the sample being decomposed under the action of endogenous enzymes and exogenous enzymes secreted by microorganisms, producing alkaline substances such as ammonia and amines, resulting in A significant increase in pH value. The color difference measurement revealed the change of meat quality color, and the L*, A* and B* values in all parts decreased. These changes are closely related to the formation of flavor. The results of principal component analysis showed that the overall flavor of fried beef was different under the same ripening time, different ripening temperature, humidity and wind speed. According to the analysis of volatile components and relative content in beef of the three groups, and the calculation of beef comprehensive scoring equation, the results showed that the blank group was < control group < experimental group. The experimental group (B) had the best flavor. This study revealed the dynamic changes of flavor compounds in meat ripening process under different ripening time and treatment methods, and the research results have important guiding significance for optimizing the ripening process of pan-fried meat and improving the quality of meat.

Keywords: Beef; Dry Aged; Volatile substances; SPME-GC-MS.

1. Introduction

1.1. Research background

Beef is a high-protein, low-fat and low-cholesterol food, rich in essential amino acids, fatty acids, vitamins and minerals. It is a widely eaten meat that can meet people's needs for protein and nutrition. Dry ripening is an effective means to improve the quality of meat. Through the specific mature process, the beef tenderness, flavor, water retention, color and oxidation stability can be improved.The fried dried mature beef has a unique barbecue flavor, roasted nut flavor, butter flavor and other pleasant flavor characteristics[1]，these flavor substances mainly originate from processes such as lipid oxidation, protein decomposition, water loss, and microbial activities.With the growing demand of consumers for high-quality meat, the market of mature meat products has huge space for development.

1.2. Dry maturing

Dry aging is a meat processing technology that refers to the process of aging meat in an aerobic environment at specific humidity and temperature conditions for weeks or even months, which improves the texture and flavor of the meat[2].Dry Aged Beef (DA Steak) is a process that loosens muscle fibers, air-dries and hardens the surface, and locks in internal juices through natural decomposition and enzyme action.In the process of ripening, inosine, guanyline and hypoxanthine[3],thus stimulating a more rich, complex flavor and juicy taste.This process takes about 35 days, during which the surface of the beef will become hard and not suitable for consumption. Usually, 30% -50% of the beef in the outer circle will be trimmed off, and only the essence of the middle will be retained, making the meat more tender and rich in flavor. The steak is cooked by frying. The short time of high temperature makes the surface water of the steak evaporate quickly, and the internal water evaporation is blocked, thus forming the coke outside and the tender taste inside. Steaks with different cooked conditions produce different caramelization and Maillard reactions, thus affecting the color and flavor.

Flavor is an important factor in determining the quality of meat products and influences the consumer's desire to buy. Differences in flavor characteristics between dry-aged and non-dry-aged process beef[4].There have been some representative studies on the flavor difference of different parts of beef in the process of dry ripening.ZHU He et al[5]used gas-MS combined technology to analyze the changes of flavor substances in different parts of beef during dry ripening.Yu Qianqian et al[6] focused on the influence of dry maturity on meat quality and its mechanism, and the key parameters of dry maturity technology have a significant

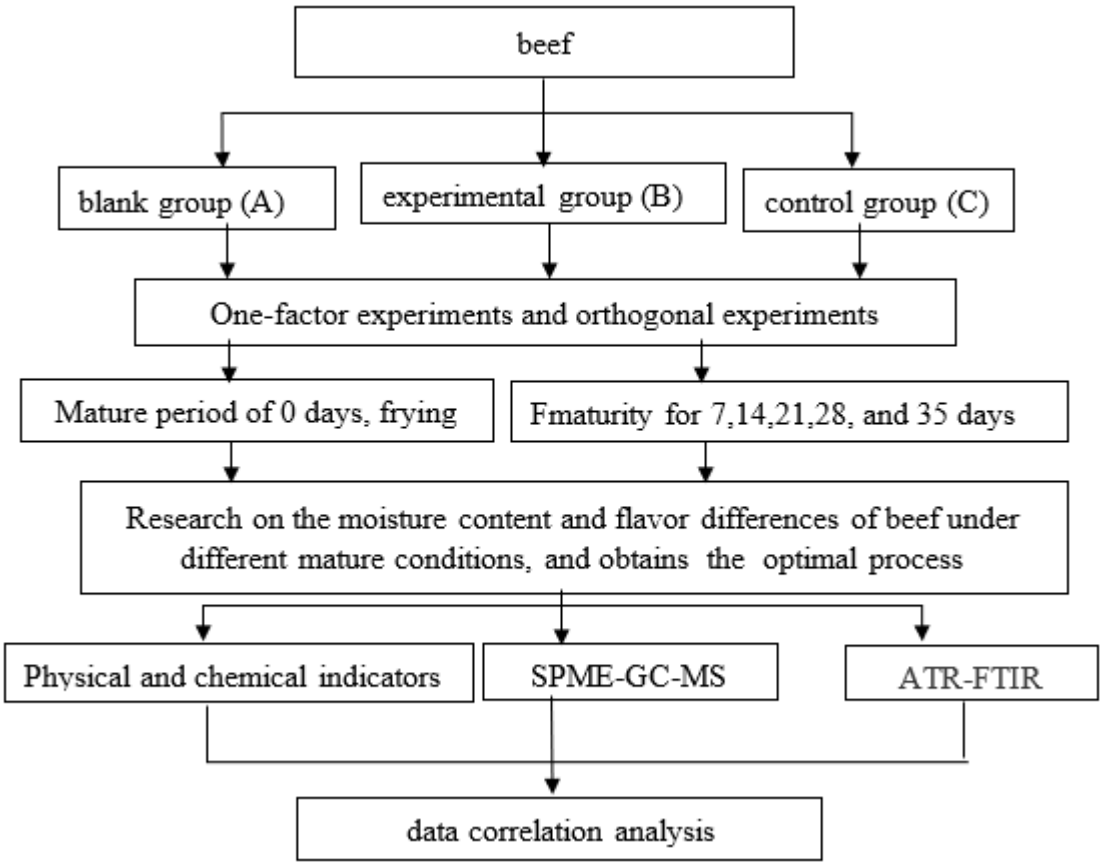
impact on the quality of beef.Through the study of Cui Yan[7], we know that the flavor substances in the muscle tissue of Yanbian yellow cattle are diverse, and its formation is affected by many factors.Through ultra-efficient liquid chromatography-mass spectrometry, Liu Meng et al.[8]analyzed the metabolites of cattle top brain meat at different maturity stages, and found that the formation of flavor and nutrients is a complex process involving multiple metabolites. However, the research on volatile flavor compounds and quality effects of fried beef with different ripening conditions is not comprehensive.

1.3. Study content and purpose

This study mainly focuses on the different dry ripening conditions and the influence of cooking degree on beef quality, including the research on its physicochemical properties, sensory evaluation, flavor formation mechanism and moisture content. By optimizing the process conditions, improving the efficiency and quality of cooked meat, and establishing scientific quality evaluation standards, to provide basic theory and data reference for the production practice of cooked meat.

Shoulder meat of chilled cattle was taken and blank group A (fresh meat), experimental group B (humidity 40% in the first stage and 80% in the second stage) and control group C (humidity 85%) were selected. The optimal ripening process was derived by comparing different ripening times, ripening temperatures and air flow rates in a one-way and sensory evaluation. The maturation cycle was 35 days, and samples were taken on days 0, 7, 14, 21, 28, and 35, respectively, and the variability of pH, color, and moisture content was determined after frying, followed by principal component analysis of the relative content of volatiles and categories, and comparative analysis of the data yielded a composite score to determine the optimal frying process for steaks. It provides certain theoretical basis for the study of volatile flavor substances in dry-aged beef and the development of beef products.

1.4. Technological route



2. Materials and Methods

2.1. Experimental material

2.1.1. Selection and processing of the beef samples

Selected Simmental crossbred yellow beef, 48 hours after slaughter, stored at a temperature of -18 ℃ transported to the laboratory, selected part of the sirloin at 4 ℃ thawing, thawing, aseptic conditions, remove the surface fascia, trimming and flattening, transferred to the dry maturation cabinet, control humidity, wind speed and maturation time.

2.1.2. The main reagent

The main test reagents are shown in Table 2-1

Table 2-1.

Reagent name	company
Anhydrous ethanol (analytically pure)	Fuchen (Tianjin) Chemical Reagent Co.
95% ethanol	Fuchen (Tianjin) Chemical Reagent Co.
double distilled water	Jinklon (Beijing) Biotechnology Co.

2.1.3. Instruments and equipment

The main test instruments are shown in Table 2-2

Table 2-2. Main test instruments

Instrument name	model	company
pH meter	testo205	Han Sodium Instruments (Shanghai) Co.
colorimeter	CR-400//410	Konami Minolta (China) Co.
Electronic Analytical Balance	ISO 9001	Beijing Sartorius Balance Co.
Polystar Near Infrared Analyzer	SupNIR-1500	Shenzhen Jushida Technology Co.
SICAO New Wave Dry Maturing Cabinet	DA400S	Shenzhen Xinchao Electric Co.
Metal bath+solid phase microextraction probe holder	KLo1	Beijing Kanglin Technology Co.
Drum drying cabinet	pH-240A	Shanghai Yiheng Scientific Instrument Co.
Fourier Infrared Spectrometer	Nicolet iS5	Thermo Fisher Scientific
Gas-Mass Analyzer	7890A	Agilent Technologies Ltd.

2.2. Experimental method

2.2.1. Dry-cooked and frying process

Simmental crossbred Lusi yellow cattle were thawed at 4°C. After thawing, the surface fascia was removed, trimmed and flattened, and then transferred to dry aging cabinets, where they were cooked at different dry aging times (7d, 14d, 21d, 28d, and 35d), temperatures (0°C, 1°C, 2°C, 3°C, and 4°C), wind speeds (0m/s, 1m/s, 2m/s, 3m/s, and 4m/s), and humidity fixations (40% in the early stage, and 80% in the late stage)[9]for ripening. The matured samples were stored in a freezer at -18℃ for subsequent analysis.

Referring to the frying method of Huang Jia et al[10] with slight modification. The steak was thawed at 4 ℃ and then cut into 6.0 cm×8.0 cm×1.2 cm, the power of the induction cooker was 2100 W, and 8.0 g of cooking oil was added to a non-stick pan, and the steak was pan-fried when the oil temperature was measured to be 280 ℃ by an infrared thermometer, and the steak was turned over every 30 s. The meat samples were connected to a digital thermometer with a K-type thermocouple probe for the determination of the center temperature until the center temperature of the meat samples rose to 60 ℃. The meat samples were removed immediately, and then cooled to room temperature after absorbing the oil stains on the surface, and stored in a freezer at -18 ℃ for subsequent analysis.

2.2.2. Measurement Methods

2.2.2.1 single factor experiment

In the process of dry ripening, ripening time, temperature and wind speed are the main factors affecting the sensory quality. In this study, the best cooked beef was made according to 2.1.1 beef samples and 2.2.1 dry preparation. The ripening time, temperature and wind speed were tested to determine the optimal processing process.

(1) Single-factor experiment of ripening time

The ripening times were 7 d, 14 d, 21 d, 28 d, and 35 d. Other influencing factors were fixed, and the temperature (2°C), relative humidity (85%±5%), and air flow rate (2 m/s) were set for ripening to obtain dry-aged beef. The optimal ripening time was determined by sensory evaluation.

(2) One-way experiment on air flow rate

In order to investigate the effect of air flow velocity on the traditional dry aging process of beef tenderloin, the samples were traditionally dry-aged at a temperature of 2℃ and a relative humidity of 80% for 21d at air flow velocities of 0.5, 1, 1.5, 2, 2.5m/s, and the effect of air flow velocity on the quality of dry-aged beef was monitored. The optimal air flow rate was determined by sensory evaluation.

(3) One-way experiment on optimal temperature

In order to investigate the effect of temperature on the traditional dry-aging process of beef tenderloin, five temperatures were set at 0℃, 1℃, 2℃, 3℃ and 4℃, and the beef tenderloin was traditionally dry-aged for 21d at a relative humidity of 80% and an air flow rate of 2 m/s, and the effect of temperature on the quality of dry-aged beef was monitored. The optimal maturation time was determined by sensory evaluation.

2.2.2.2 orthogonal experimental design

On the basis of one-factor test, three factors, ripening time, ripening temperature and air flow rate were selected for L9 (33) orthogonal test, and the sensory score was taken as the evaluation index. The factor level design is shown in Table 1.

Table 1-1. Level of orthogonal experimental factors

level	A ripening time day	B ripening temperature ℃	C air flow rate m/s
1	19day	1℃	1.0m/s
2	21day	2℃	1.5m/s
3	23day	3℃	2.0m/s

2.2.2.3 Sensory assessment and scoring criteria

Referring to the methods of Pan Yongjiang et al[11] and Li Changfu et al[12]with minor modifications.The evaluation team is composed of 5 food industry experts and 5 food processing and safety researchers who have received food sensory identification training. A total of 10 people, men and women, jointly formulate the sensory scoring standards for dry cooked beef, and the members of the scoring group conduct scores in the professional sensory evaluation laboratory.

Table 2-3. The Sensory Evaluation Form

Evaluation Indicators	Sensory evaluation criteria	grade
Color(25 points)	Colorful, bright deep red	17-25
	Gradual dulling of color, dark red in color	9-16
	Dull, dark color	0-8
Organization(25 points)	Muscle tissue is dense and intact, with clear texture	17-25
	Muscle tissue is not dense, but not loose	9-16
	Muscle tissue is not dense, loose	0-8
Odor(25 points)	Dry-aged aroma and beefy aroma are more obvious	17-25
	Reduced dry-aged aroma with beef aroma	9-16
	Beef aroma disappeared, with spoiled odor.	0-8
Acceptability (25 points)	Strong acceptance	17-25
	Fairly acceptable	9-16
	Weak acceptance	0-8

2.2.2.4 the determination of PH

The decoction samples were cut into 1 cm × 1 cm × 1 cm pieces and measured using a PH meter, which was measured by stabbing the probe into the center of the sample. Repeat the measurement 3 times and take the average value.

2.2.2.5 Determination of color difference

The decoction samples were cut into 1 cm × 1 cm × 1 cm blocks and measured with a precision colorimeter, recording the samples L* (luminosity), a* (red) and b* (yellow). Repeated measurements were made three times from the four cut surfaces of the same sample and the average value was taken.

2.2.2.6 Determination of moisture content

Refer to GB/T5009.238-2016 "National Standard for Food Safety Determination of Moisture Activity of Food", and adopt direct drying method.

Preparation: Take clean aluminum or glass flat weighing bottle, put it in 104℃ drying oven, with the cap obliquely supported on the side of the bottle, heat it for 1.0h, take it out and cover it well, put it in the desiccator and cool it for 0.5h, weigh and repeat drying to the difference of quality between before and after the two times is not more than 2mg, that is, it is the constant weight.

Formal experiments: chop the beef sample, weigh 2g (accurate to 0.0001g), into the weighing bottle, the thickness of the sample placed in a 104 ℃ drying oven, the bottle lid diagonally supported on the bottle side, dry 2h-4h, cover and remove, put into a desiccator to cool down 0.5h after weighing. Then put it into the 104 ℃ drying oven to dry for about 1h, take it out and put it into the desiccator to cool for 0.5h before weighing. Repeat the above operation until the difference in mass between the two times is not more than 2mg, which is the constant weight.

The moisture content was determined as follows:

$$X=\frac{(m1-m2)\times 100}{m1-m3}$$

In the formula:

X - the moisture content of the sample, in grams per hundred grams (g/100g)

m1 - the mass of the weighing flask and the specimen in grams (g)

m2 - weighing bottle and the sample after drying the mass, in grams (g)

m3 - the mass of the weighing bottle, in grams (g)

100 - unit conversion factor

2.2.2.7 Determination of the Fourier transform near-infrared spectrum

The method was referred to and slightly modified from Li Jiasan et al [13].Sample preparation: a small amount of beef sample was taken and ground into powdered granules to collect spectral information. Spectral acquisition: The dried sample powder was spread on the wafer of the Fourier transform infrared spectrometer and scanned, using the air background as the reference, with a scanning range of 4000-400 cm-1, the signal scanning was accumulated 32 times, and the scanning resolution was 4 cm-1, the infrared spectra were collected, and the scanning was repeated three times for each processed spectrum. The measured infrared spectra were automatically smoothed, baseline corrected and normalized in vertical coordinates using OMNIC software, and the data were exported in CSV format and plotted with wave number as the horizontal coordinate and transmittance as the vertical coordinate.

2.2.2.8 Determination of volatile flavor substances

The method of Yujing Cai et al [14].was adopted with slight modification. The solid phase microextraction-gas chromatography-mass spectrometry (SPME-GC-MS) technique was used to determine the volatile flavor substances.

Headspace conditions: 2 g of sample was taken in a 20 mL sample vial, sealed, placed in a metal bath at 60 ℃ and equilibrated for 1800 s. Then an aged (250 ℃, 600 s) extraction head was inserted into the sample vial to extract for 2400 s. After the extraction was completed, it was inserted into the GC-MS injection port and desorbed for 600 s. The extracted sample was then analyzed by SPME-GC-MS for the determination of the volatile flavors.

Gas phase conditions: inlet temperature: 250 ℃; chromatographic column: HP-5MS (60 m×250 μm, 0.25 μm); heating procedure: the starting temperature of 40 ℃, held for 60 s, 5 ℃/min to 250 ℃, held for 300 s. Carrier gas: high purity helium, flow rate of 1 mL/min, shunt ratio of 4:1.

Mass spectrometry conditions: EI ion source, electron bombardment energy of 70 eV, ion source temperature of 230 ℃; full scan; mass scanning range (m/z): 35~350 amu; standard tuning file.

2.3. Data processing

Excel was used to organize and summarize the data, SPSS version 26 was used for ANOVA, and Origin2021 was used for graphing.

3. Results and Analysis

3.1. Univariate outcome analysis

3.1.1. Determination of the ripening time

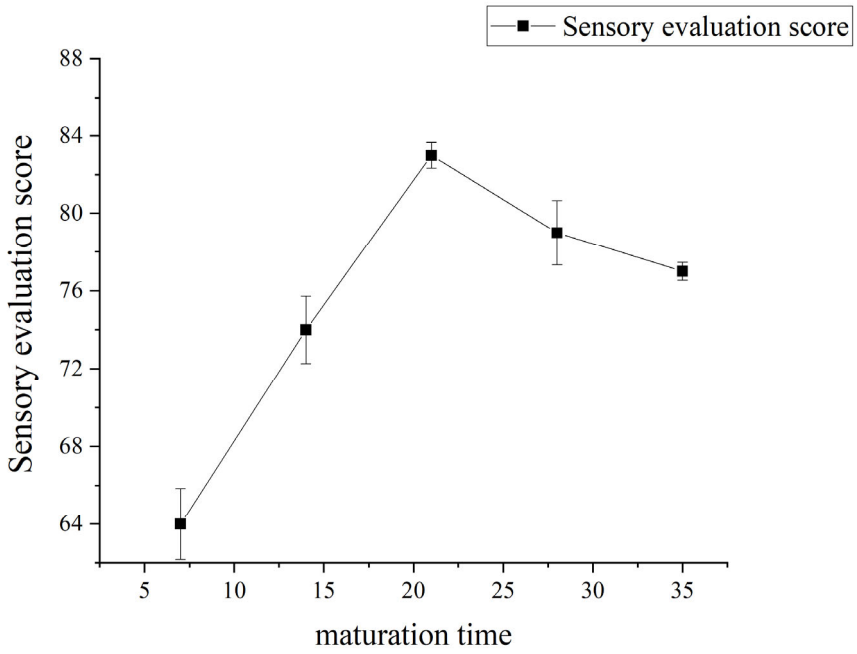


Figure 3-1. Effect of time on the senses

From Figure 3-1, with the increase of ripening time, the sensory evaluation score gradually increased and then decreased, reaching the highest score at 21 days. The cooked time has an optimal value in sensory characteristics, that is, the highest sensory score at 21 days, and the best sensory evaluation score between 14 and 28 days, yielding higher quality dry cooked beef.

3.1.2. Determination of the ripening temperature

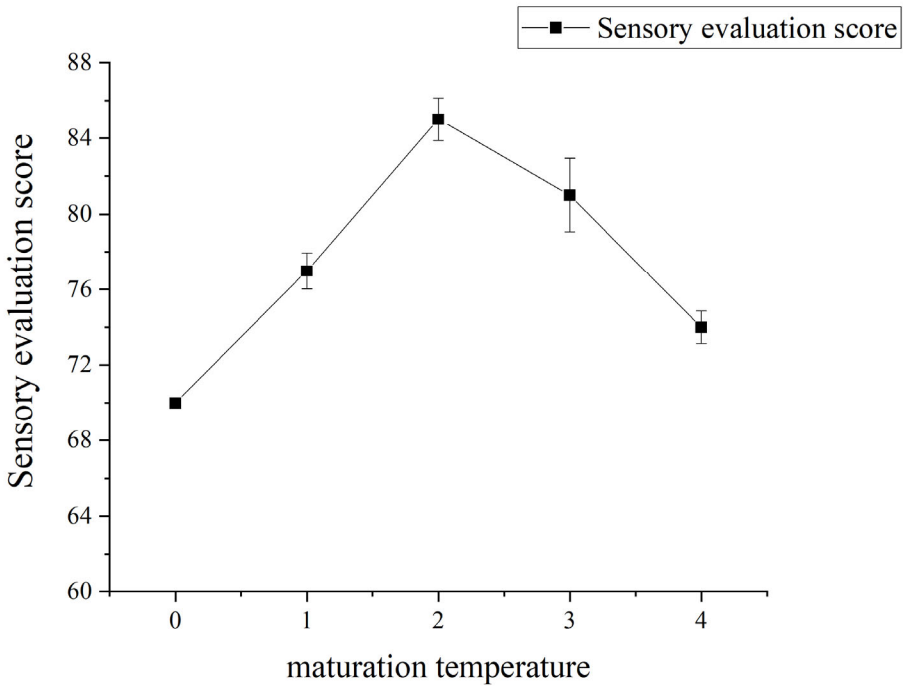


Figure 3-2. Effect of temperature on the senses

From Figure 3-2, as the ripening temperature increases, the sensory evaluation score gradually increases and then decreases, and reaches the highest score at 2℃. The cooked temperature has an optimal value in sensory characteristics, that is, the sensory score is the highest at 2℃, the sensory evaluation score between 1 and 3℃ is the best, and the dry cooked beef with strong aroma is obtained.

3.1.3. Determination of the air flow velocity

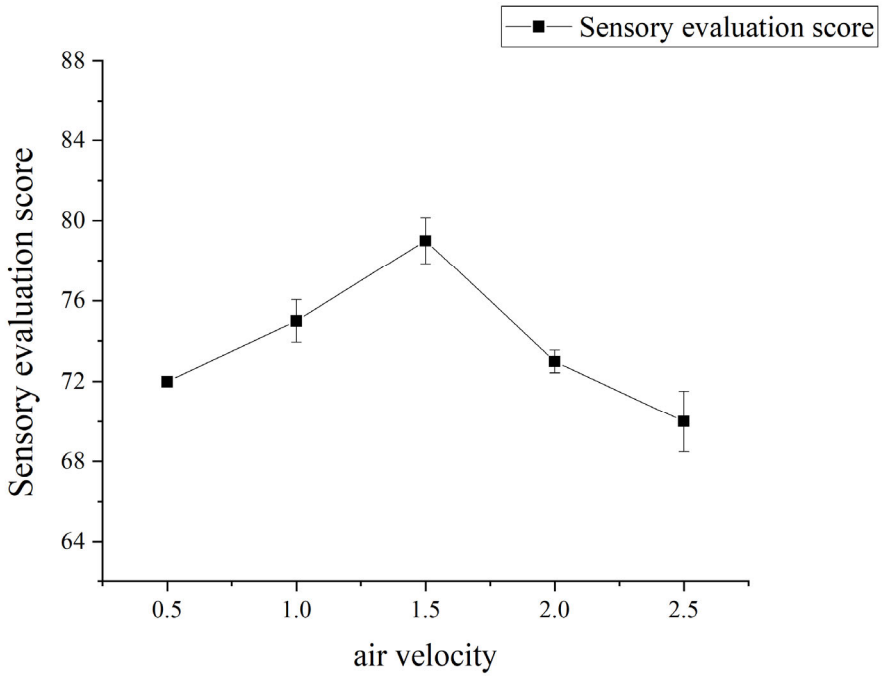


Figure 3-3. Effects of the air flow rate on the senses

From Figure 3-3, with the increase of the air flow rate, the sensory evaluation score gradually increases and then decreases, and reaches the highest score at 2 m/s. The air flow rate has an optimal value in sensory characteristics, that is, the highest sensory score at 2 m/s, and the sensory evaluation score of the air flow rate between 1 and 3 m/s is the best, yielding higher quality dry cooked beef.

3.2. Analysis of orthogonal results

On the basis of the single-factor test, three factors, namely, ripening time, ripening temperature and air flow rate, were selected to carry out the L9(33) orthogonal test, and the sensory score was used as the evaluation index, and the results of the orthogonal experiments are shown in Table 3-1.

Based on the magnitude of the R value of the extreme deviation, the main order of the influence of each factor on the sensory score was A＞B＞C, i.e., the influence of the ripening time was the largest, the ripening temperature was the second largest, and the air flow rate had the smallest influence on the finished product. Based on the K-value, A2＞A3＞A1, B2＞B3＞B1, C3＞C2＞C1, and the sensory score, the optimal combination was A2B2C3, which resulted in the optimal processing conditions for dry-aged beef: 21 days of aging time, aging temperature of 2℃, and air flow rate of 2m/s. The optimal processing conditions for dry-aged beef were as follows: 21 days of aging time, 2℃ of aging temperature, and 2m/s of air flow rate.

Table 3-1. Results of the orthogonal experiments

Experimental serial number	factor			Sensory score
	A ripening time day	B ripening temperature ℃	C air flow rate m/s	
1	1	1	1	74.67
2	1	2	2	78.00
3	1	3	3	78.67
4	2	1	2	78.30
5	2	2	3	82.33
6	2	3	1	79.00
7	3	1	3	78.33
8	3	2	1	79.00
9	3	3	2	78.33
K1	77.113	77.100	77.557	
K2	79.877	79.777	78.210	
K3	78.553	78.667	78.657	
k1	25.700	25.700	25.852	
k2	26.626	26.592	26.070	
k3	26.184	26.592	26.219	
R	2.764	2.677	2.220	A>B>C

3.3. Changes in PH values

Table 3-2. pH comparison of beef with different treatments at different ripening times

Maturity formation time (days)	blank group (A)	experimental group (B)	control group (C)
0	5.58±0.01e	-	-
7	-	5.57±0.03e	5.64±0.03e
14	-	5.64±0.03de	5.66±0.02de
21	-	5.76±0.04dc	5.81±0.05c
28	-	5.97±0.13b	6.01±0.2b
35	-	6.31±0.04a	6.43±0.07a

* Different letters in each column indicate the difference reaching a significant level (P (0.05), and the same letter means not reaching a significant level (P (0.05).

By measuring the pH value of meat, we can understand the pH of meat, so as to judge its freshness[15]. As shown in Table 3-2, in the initial ripening period, day 0 PH is higher than 7 days, it may be the muscle glycogen anaerobic yeast to produce lactic acid and ATP decomposition to produce phosphate root, which significantly reduces the pH of the sample. There was a significant difference between the PH value of group B and group C on 21 days of ripening. The PH value of group B was lower than that of group C, possibly because the low humidity and wind speed treatment made the beef shell quickly in a short time, forming a protective barrier to prevent the continued infection of microorganisms, and the level of exogenous enzymes secreted by microorganisms decreased, and the pH value increased slowly. As the ripening proceeds, the pH value of the samples ripening under different conditions tends to rise. It may be that the protein in the sample is decomposed under the action of endogenous enzymes and exogenous enzymes secreted by microorganisms, producing alkaline substances such as ammonia and amines, which makes a significant increase in the pH value. According to the freshness standard of meat samples, the PH value are within the range of secondary fresh meat samples (pH6.2~6.6), and group B is better than group C.

3.4. Changes in color difference

Table 3-3. Comparison of beef color differences between different groups at different ripening times

time /d	L*			a*			b*		
	blank group (A)	experimental group (B)	control group (C)	blank group (A)	experimental group (B)	control group (C)	blank group (A)	experimental group (B)	control group (C)
0	40.55±0.25	40.55±0.25^{a}	40.55±0.25^{a}	7.47±0.18	7.47±0.18^{d}	7.47±0.18^{c}	15.42±0.25	15.42±0.25^{b}	15.42±0.25^{a}
7	-	36.99±1.23^{b}	38.82±1.03^{a}	-	16.06±0.68^{a}	15.70±0.70^{a}	-	17.62±0.28^{a}	15.14±1.38^{a}
14	-	25.70±0.17^{c}	26.75±1.35^{b}	-	11.44±0.30^{c}	10.96±0.22^{c}	-	8.79±1.47^{c}	7.67±0.26^{b}
21	-	23.28±0.37^{d}	23.90±1.27^{c}	-	14.41±0.66^{Ab}	12.41±0.64^{Bb}	-	3.72±0.26^{Bd}	4.53±0.28^{Ac}
28	-	22.90±1.08^{d}	22.88±0.57^{c}	-	14.18±0.48^{b}	12.59±0.80^{b}	-	3.68±0.29^{d}	3.93±0.17^{c}
35	-	22.01±0.39^{d}	21.85±0.65^{c}	-	14.13±0.54^{b}	12.75±0.26^{b}	-	3.32±0.23^{d}	3.53±0.22^{c}

* lowercase letters indicate significant differences between the same groups at different times (P <0.05), and uppercase letters indicate significant differences between different groups at the same time(P <0.05).

The color of meat affects the purchasing power of consumers[16],and the hue values (L*, a*, b*) are generally used to indicate the color. The higher the brightness value (L*), the better the gloss of the meat; the higher the redness value (a*), the brighter the red of the meat sample and the fresher the quality of the meat; the higher the yellowness value (b*), the less fresh the meat. As shown in Table 3-3, there were significant differences in a* values among different groups at 21 days of maturation. For example, the a* value of the experimental group was lower than that of the control group, probably due to the fact that the PH value of the experimental group was significantly lower than that of the control group, and the low PH favored the formation of high iron myoglobin, which formed a brownish color, resulting in a lower a* value.

Combined with Table 3-3, there was an overall trend of decreasing L* values in the experimental and control groups. This may be due to the decrease in moisture content, which reduces the scattering effect of light as well as the exposure of myoglobin in beef to oxygen in the air, which is oxidized to high iron myoglobin and forms a brownish color in a low oxygen state, resulting in an overall decrease in the L* value. During the frying process, the muscle fibers contracted at high temperatures, resulting in less ability to reflect light and darkening of the meat. The a* values of the experimental and control groups showed a tendency to first decrease and then increase with the increase in cooking time. In the early stage of ripening, the red color in the meat gradually became lighter due to the production of high iron myoglobin by oxidation reaction and thermal denaturation of myoglobin at high temperature during frying, resulting in lower a* values. In the later stages of maturation, it is due to the gradual decrease in moisture content, the formation of a hard shell on the surface of the beef that blocks the internal myoglobin from contact with oxygen in the air as well as the loss of juices during maturation concentrating the myoglobin and iron, among others [17], leading to an increase in the a* value. The overall decreasing trend of b* values in the experimental and control groups was similar to the findings of Jin Ying et al [18].

Comprehensively comparing the changes in color difference between the two groups, there was no significant difference in the L* values, and there was a significant difference in the a* and b* values. The a* value of the experimental group is higher than that of the control group, and the b* value of the experimental group is lower than that of the control group both proved that the experimental group

is better than the control group.

3.5. Changes in the moisture content

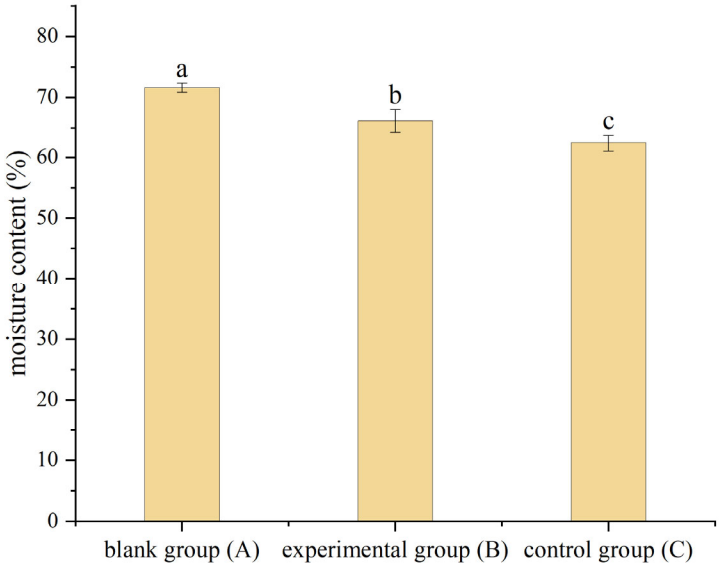


Figure 3-4. Water content of different treatments at different maturation times

As can be seen in Figures 3-4, the moisture content of beef showed a decreasing trend during dry aging, with a significant decrease in the moisture content of beef occurring from 0 days of dry aging (fresh meat group) to 21 days (experimental and control groups) due to the fact that the dry aging process is accompanied by a large amount of water evaporation. The trend that moisture content decreases with increasing maturation time is in agreement with the findings of Lee et al [19]. There was a significant difference between the experimental group (B) and the control group (C) for the same time of 21 days ripening. During the pre-ripening period, group B was exposed to low humidity and the rapid drying of surface moisture to form a hard shell prevented the internal moisture dissipation, resulting in higher moisture content in group B than in group C. The moisture content in group B was higher than that in group C. The moisture content in group B was higher than that in group C.

3.6. Changes in the Fourier IR

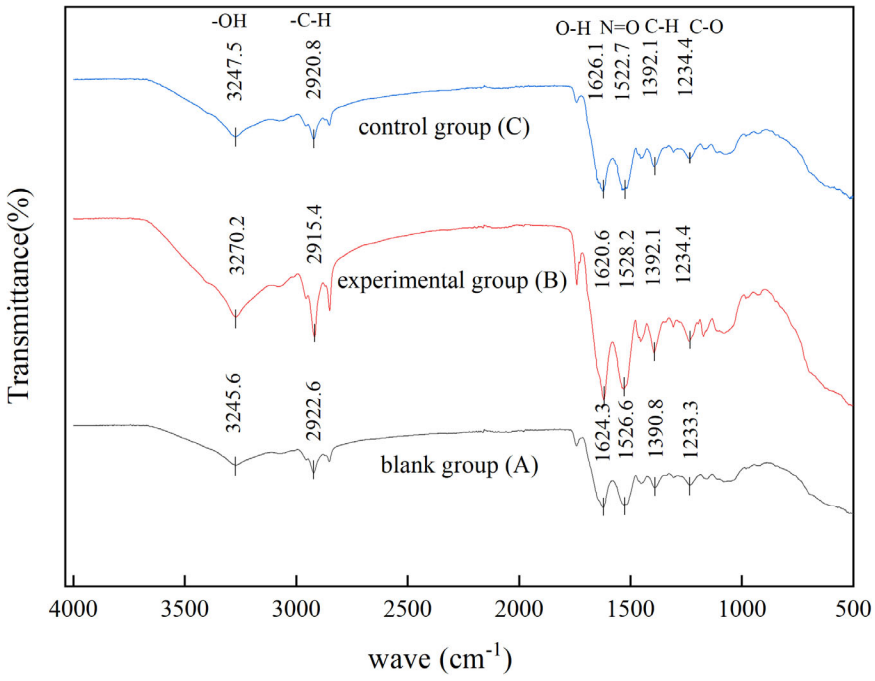


Figure 3-5. Fourier spectroscopic analysis of different treatments at different maturation times

As can be seen from Figs. 3-5, the peak intensities gradually increase in the order of blank group (A) < control group (B) < experimental group (C). The main characteristic peaks are as follows: the broad peak at 3200 cm^{-1} is caused by the symmetric and asymmetric telescopic vibration of O-H, as well as the bonding between hydrogen bonds, and the O-H bond absorption peak is the main manifestation of water in the infrared spectra; there is a C-H telescopic vibration of saturated hydrocarbons at 2850~3000 cm^{-1}, which may be methyl or methylene; the absorption peak near 1620 cm-1 is the O -H bond surface shear bending vibration; 1500~1580cm-1 there is N=O group, may be nitro

compounds; 1350~1470cm^{-1} corresponding to the group is C-H, there is methyl or methylene bending or deformation vibration, through the peak at 1000~1300cm^{-1} peak corresponding to the functional group that there are alcohols, phenols, ethers, esters, and carboxylic acids of the C-O telescopic vibration. The C-O stretching vibration of alcohols, phenols, ethers, esters and carboxylic acids is derived here from the peaks corresponding to 1000~1300 cm^{-1} .

3.7. Changes in the volatile substances

3.7.1. Total ion flow plot of the beef volatile flavor components GC-MS

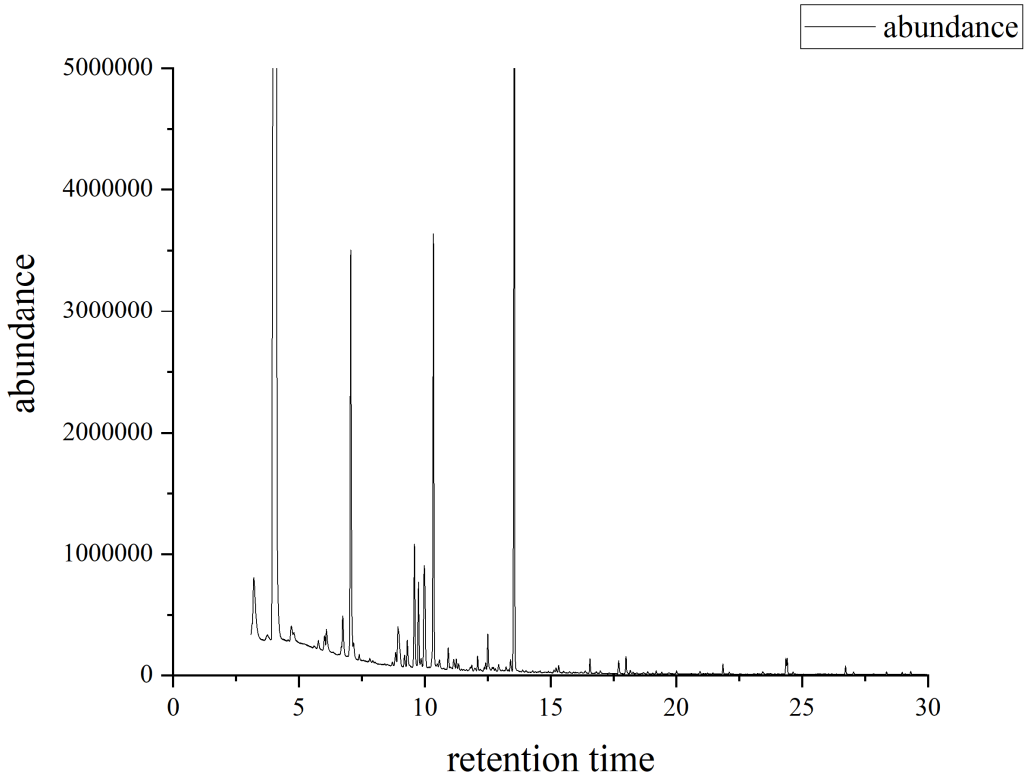


Figure 3-6. Total ion flow diagram of GC-MS in the blank group (A)

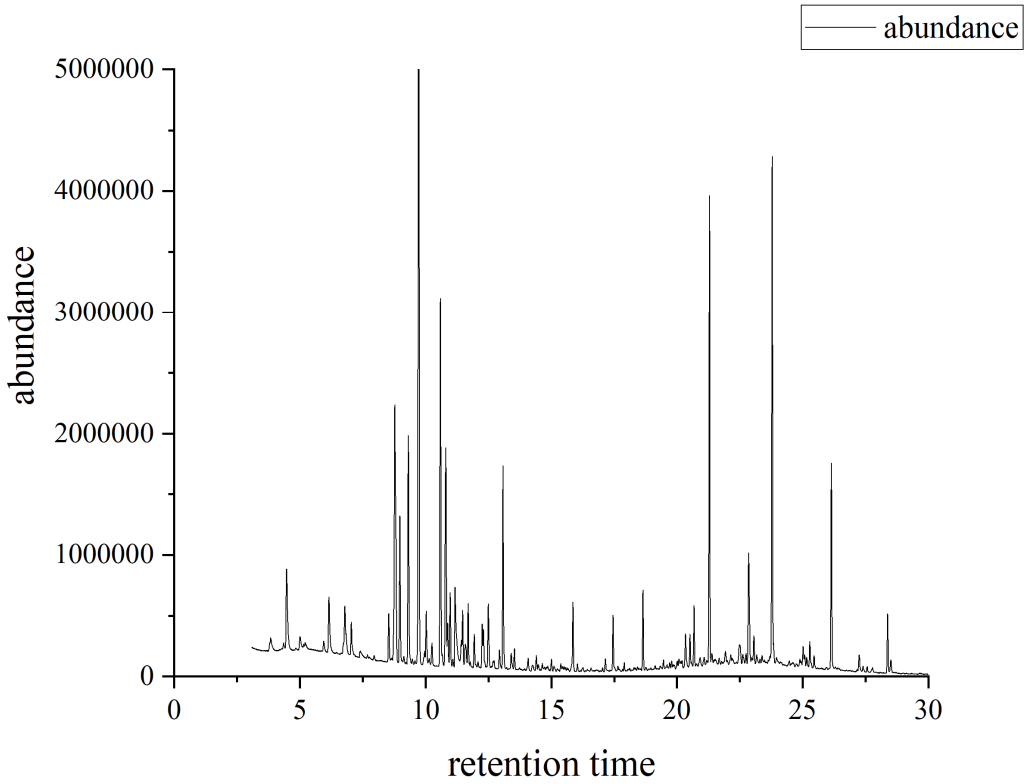


Figure 3-7. Total ion flow diagram of GC-MS in experimental group (B)

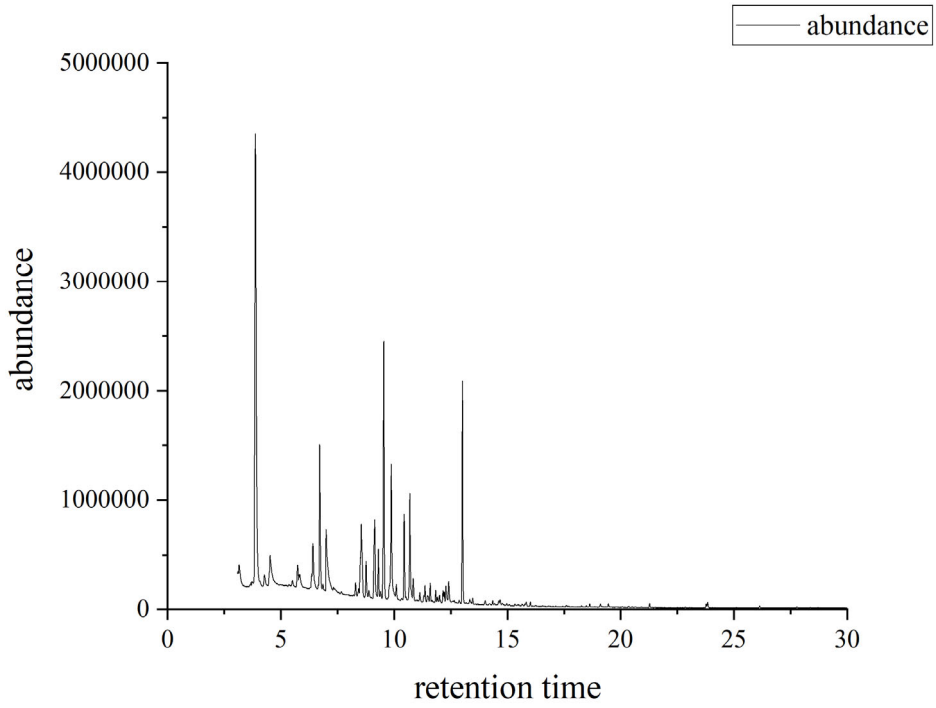


Figure 3-8. Total ion flow diagram of GC-MS in the control group (C)

3.7.2. Analysis of the volatile flavor composition and relative content of the butter

Table 3-4. List of volatile compounds in dry-aged beef

category	order number	Substance name	chemical reaction	relative content/%		
				blank group (A)	experimental group (B)	control group (C)
Hydrocarbons	1	Benzene, 1,3-dimethyl-	C8H10	0.279%	3.075%	-
	2	o-Xylene	C8H10	-	-	1.013%
	3	Pentylcyclopropane	C8H16	-	14.924%	0.331%
	4	Indene	C9H10	-	1.288%	-
	5	2-Methylstyrene	C9H10	-	-	0.842%
	6	n-Propylbenzene	C9H12	-	0.888%	0.474%
	7	2-Ethyltoluene	C9H12	-	4.115%	3.900%
	8	Homotrimethylbenzene	C9H12	-	8.687%	2.911%
	9	Bi-Trimethylbenzene	C9H12	0.473%	-	1.293%
	10	1,2,4-Trimethylbenzene	C9H12	-	-	9.441%
	11	4-Ethyltoluene	C9H12	-	7.141%	-
	12	Naphthalene	C10H8	-	0.138%	0.074%
	13	4-vinyl-1,2-dimethylbenzene	C10H12	0.084%	0.480%	0.316%
	14	(3E,5E)-2,6-dimethyl-1,3,5,7-octatetraene	C10H14	0.122%	0.120%	0.327%
	15	3-Propyltoluene	C10H14	0.077%	0.972%	0.713%
	16	2-Ethyl-p-xylene	C10H14	0.063%	1.710%	0.915%
	17	P-cymene	C10H14	0.051%	0.198%	-
	18	1,3-dimethyl-4-ethylbenzene	C10H14	-	1.850%	-
	19	4-isopropyltoluene	C10H14	0.130%	-	-
	20	1,3-diethylbenzene	C10H14	-	0.530%	0.195%
	21	5-Ethyl-3,5-dimethylbenzene	C10H14	-	-	0.640%
	22	4-propyltoluene	C10H14	-	1.148%	0.372%
	23	3-Ethyl-o-dimethylbenzene	C10H14	-	-	0.584%
	24	o-Isopropylbenzene	C10H14	-	-	0.325%
	25	1,2,4,5-Tetramethylbenzene	C10H14	-	0.680%	0.178%
	26	3-Carene	C10H16	0.178%	0.919%	-
	27	3-Methylundecane	C12H26	-	0.178%	-
	28	n-Dodecane	C12H26	-	1.198%	
	29	Tridecane	C13H28	0.035%	1.340%	-
	30	Heptylcyclohexane	C13H26	-	0.133%	-
	31	Tetradecane	C14H30	0.111%	6.998%	0.514%
	32	n-Pentadecane	C15H32	0.186%	8.123%	-
	33	4-Methyltetradecane	C15H32	-	0.514%	-
	34	2,6,10-Trimethyldodecane	C15H32	-	0.974%	-
	35	n-Hexadecane	C16H34	0.099%	3.311%	-
	36	2,6,10-Trimethyltetradecane	C17H36	-	2.182%	-
	37	n-Heptadecane	C17H36	-	0.932%	-

	38	n-nineteenthane	C19H40	-	0.100%	-
	39	2,6,10,14-Tetramethylheptadecane	C21H44	0.042%	2.504%	-
	40	3,5,24-Trimethyltetradecane	C43H88	0.026%	-	0.136%
	1	n-Hexanal	C6H12O	59.261%	-	26.251%
	2	Benzaldehyde	C7H6O	1.121%	-	0.965%
	3	Heptanal	C7H14O	6.385%	0.784%	5.573%
	4	n-Octanal	C8H16O	5.429%	0.926%	6.647%
	5	l-alpha-octulose	C8H16O8	-	-	0.209%
	6	4-Ethylbenzaldehyde	C9H10O	0.106%	-	-
	7	(E,E)-2,4-nonadienal	C9H14O	0.027%	-	-
	8	trans-2-Nonanal	C9H16O	0.077%	-	-
	9	nonanal	C9H18O	11.411%	3.826%	6.839%
Aldehydes	10	trans-2-Decenal	C10H180	0.045%	-	-
	11	decanal	C10H20O	0.174%	0.132%	0.136%
	12	(E,E)-2,4-Dodecadienal	C12H20O	-	-	0.163%
	13	Undecanal	C11H22O	0.024%	-	-
	14	Dodecanal	C12H24O	0.058%	-	-
	15	Tetradecanal trimer	C14H28O	-	-	0.070%
	16	(Z)-7-hexadecenal	C16H30O	-	0.208%	0.112%
	17	cis,cis,cis-7,10,13-hexadecatrienal	C16H26O	0.042%	-	-
	18	n-Pentadecanal	C15H30O	0.071%	-	-
	19	(Z)-13-octadecadienal	C18H34O	-	0.175%	-
	1	2-Heptenone	C7H14O	0.732%	-	2.340%
	2	Methylheptenone	C8H14O	0.156%	-	0.312%
	3	Levocarvone	C10H14O	0.187%	0.214%	-
Ketones	4	3-Dodecyl-2,5-furandione	C16H26O3	-	0.244%	-
	5	2H-3,9a-Ethylcyclopenta[b]oxepin-2-one	C16H26O2	-	0.117%	-
	6	3,5-bis(2,5-dimethylphenyl)-2,3-dihydro-1H-indenone	C25H24O	-	-	0.122%
Acids	1	Acetic acid	C2H4O2	0.239%	-	0.253%
	2	Dodecenylsuccinic anhydride	C16H26O3	-	1.049%	-
	1	n-Pentanol	C5H12O	2.495%	-	-
	2	trans-2-Methylcyclopentanol	C6H12O	-	2.255%	-
	3	n-Heptanol	C7H16O	0.431%	-	-
	4	(2Z)-2-Octen-1-ol	C8H16O	1.784%	-	3.973%
	5	trans-2-Octen-1-ol	C8H16O	0.114%	-	-
	6	cis-5-Octen-1-ol	C8H16O	-	-	0.198%
	7	n-Octanol	C8H18O	0.548%	-	-
	8	2-Ethylhexanol	C8H18O	-	-	3.951%
	9	6-amino-2-methyl-2-heptanol	C8H19NO	0.024%	-	-
	10	1-nitro-2-acetamido-1,2-dideoxymannitol	C8H16N2O7	-	-	0.622%
Alcohols	11	Isoparaffinol	C10H16O	0.190%	-	-
	12	L-Caryl alcohol	C10H16O	0.037%	-	-
	13	3-Decyn-2-ol	C10H18O	0.093%	-	-
	14	Eucalyptol	C10H18O	0.248%	0.749%	-
	15	Dihydrocarveol	C10H18O	-	4.547%	-
	16	3-(1H-indol-4-yloxy)-1,2-propanediol	C11H13NO3	-	-	0.295%
	17	Limonen-6-ol	C15H24O2	-	0.357%	-
	18	Z,Z-2,5-pentadecan-1-ol	C15H28O	0.028%	-	0.056%
	19	spiro[indene-2,1'(2'H)-isoquinoline]-1,3-diol	C19H21NO4	0.030%	-	-
	20	Phytol	C20H40O	-	0.656%	-
	21	1-Eicosanol	C20H42O	-	0.368%	-
	1	Benzyl carbazate	C8H10N2O2	-	0.503%	0.356%
	2	Vinyl caproate	C8H14O2	1.095%	-	1.555%
	3	CBZ-B-alanine methyl ester	C12H15NO4	-	0.252%	-
	4	1-Methyl-4-(1-methylethenyl)cyclohexanol acetate	C12H20O2	0.191%	-	-
	5	methyl ester	C13H22O3	-	-	0.088%
Ester	6	(E)-3,7-dimethyl-2,6-octadienol 3-methylbutyrate	C15H26O2	-	0.155%	-
	7	Methyl 4,7,10,13-hexadecatetraenoate	C17H26O2	-	-	0.100%
	8	Ethyl 7-[2-(ethoxycarbonyl)-3α,5β-dimethoxycyclopentyl-1]-heptanoate	C19H34O6	0.221%	-	-
	9	Phenyl 2,4-di-tert-butylbenzoate	C21H26O2	0.043%	-	
	10	Methyl 11,14-eicosadienoate	C21H38O2	-	0.496%	-
Ethers	1	Aniseed Brain	C10H12O	0.031%	-	-
Phenols	1	1-(2-hydroxyethyl)-1,2,5,5-tetramethyl-cis-naphthol (1R,2S,4as,8as)	C16H30O	-	0.288%	-
	1	Lactylamine	C3H7NO2	-	-	0.782%
	2	2-aminoimidazole-5-carboxylic acid	C4H5N3O2	0.056%	-	-
	3	2-methylpyrazine	C5H6N2	-	-	3.745%
Heterocycles and others	4	2,3-dimethylpyrazine	C6H8N2	-	-	0.524%
	5	2,5-dimethylpyrazine	C6H8N2	-	-	4.551%
	6	2,6-dimethylpyrazine	C6H8N2	-	0.254%	-
	7	1-methyl-2-pyrrolidone-4-carboxamide	C6H10N2O2	0.188%	-	-
	8	p-Dichlorobenzene	C6H4CL2	0.422%	0.463%	0.700%

9	1-methyl-1,2-epoxycyclohexane	C7H12O	0.240%	-	0.310%
10	(1-methylbutyl)-oxirane	C7H14O	0.459%	-	0.319%
11	1,2-Epoxyheptane	C7H14O	0.263%	-	-
12	1-(vinyloxy)-3-methyl-butane	C7H14O	-	0.217%	
13	N-isopropylbutan-1-amine	C7H17N	-	-	0.327%
14	Methoxyphenyl oxime	C8H9NO2	0.065%	-	-
15	2-Ethyl-3,5-dimethylpyrazine	C8H12N2	-	-	0.719%
16	N,N-Dimethylbenzylamine	C9H13N	-	2.417%	-
17	Benzpropylamine	C9H13N	0.053%	-	-
18	2-Piperidone, N-[4-bromo-n-butyl]-	C9H16BrNO	-	0.187%	-
19	2-pentylfuran	C9H14O	2.210%	-	-
20	O-decylhydroxylamine	C10H23NO	-	-	0.136%
21	N(1)-n-butyl-N(2)-benzylurea	C12H18N2O	0.167%	-	0.433%
22	1,2-dibromododecane	C12H24Br2	-	0.179%	-
23	(1-ethyl-1-hydroxypropyl)cyclic anthracene	C13H15MnO4	0.055%	-	-
24	2-Trifluoroacetoxydodecane	C14H25F3O2	-	-	0.281%
25	Fluoroquinazole	C16H8Cl2FN5O	0.041%	-	-
26	Phenethylamine, N-[(4-hydroxy)hydrocinnamoyl]-	C17H19NO2	0.114%	-	0.493%
27	pyridine-10-thia-lauroate	C17H27NO2S	0.088%	-	-
28	(2S,4aS,5R,8aR)-5-(pent-4-en-1-yl)-2-propyldecahydroquinoline	C17H31N	0.049%	-	-
29	1-[3-methoxybenzyl]-6-methoxy-3,4-dihydroisoquinoline	C18H19NO2	-	0.338%	-
30	Corydaline	C21H21NO6	0.426%	-	-
31	DL-6'-Bromolaurin	C21H26BrNO4	-	0.294%	-

Note: "-" is not detected

Table 3-5. Types and percentage of total beef volatile ingredients in different treatment methods

volatileness ingredient	blank group (A)		experimental group (B)		control group (C)	
	Category	Percentage/%	Category	Percentage/%	Category	Percentage/%
Hydrocarbons	15	1.956%	30	77.350%	21	25.494%
Aldehydes	14	84.231%	6	6.051%	10	46.965%
Ketones	3	1.075%	3	0.575%	3	2.774%
Acids	1	0.239%	1	1.049%	1	0.253%
Alcohols	12	6.022%	6	8.932%	6	9.095%
Ester	4	1.550%	4	1.406%	4	2.099%
Ethers	1	0.031%	0	0.000%	0	0.000%
Phenols	0	0.000%	1	0.288%	0	0.000%
Heterocycles and others	16	4.896%	8	4.349%	13	13.320%
Total	66		59		58	

As shown in Tables 3-4, 131 volatile flavor components were identified by SPME-GC-MS in beef under different treatments at different aging times, including 40 hydrocarbons, 21 alcohols, 19 aldehydes, 6 ketones, 1 phenol, 10 esters, 2 acids, 1 ether, and 31 heterocyclic and other compounds. These compounds are mainly produced by the flavor of beef itself, fat oxidative decomposition and Merad reaction. As shown in Tables 3-5, the composition and content of volatile components of beef with different treatments and different days of maturation differed, and 66, 59 and 58 volatile flavor components were identified in the blank group (A), experimental group (B) and control group (C), respectively. The content of hydrocarbons in group B was the largest in the total category with a high percentage of

77.711%, while the two groups AC accounted for a smaller percentage of 1.956% and 25.494%.

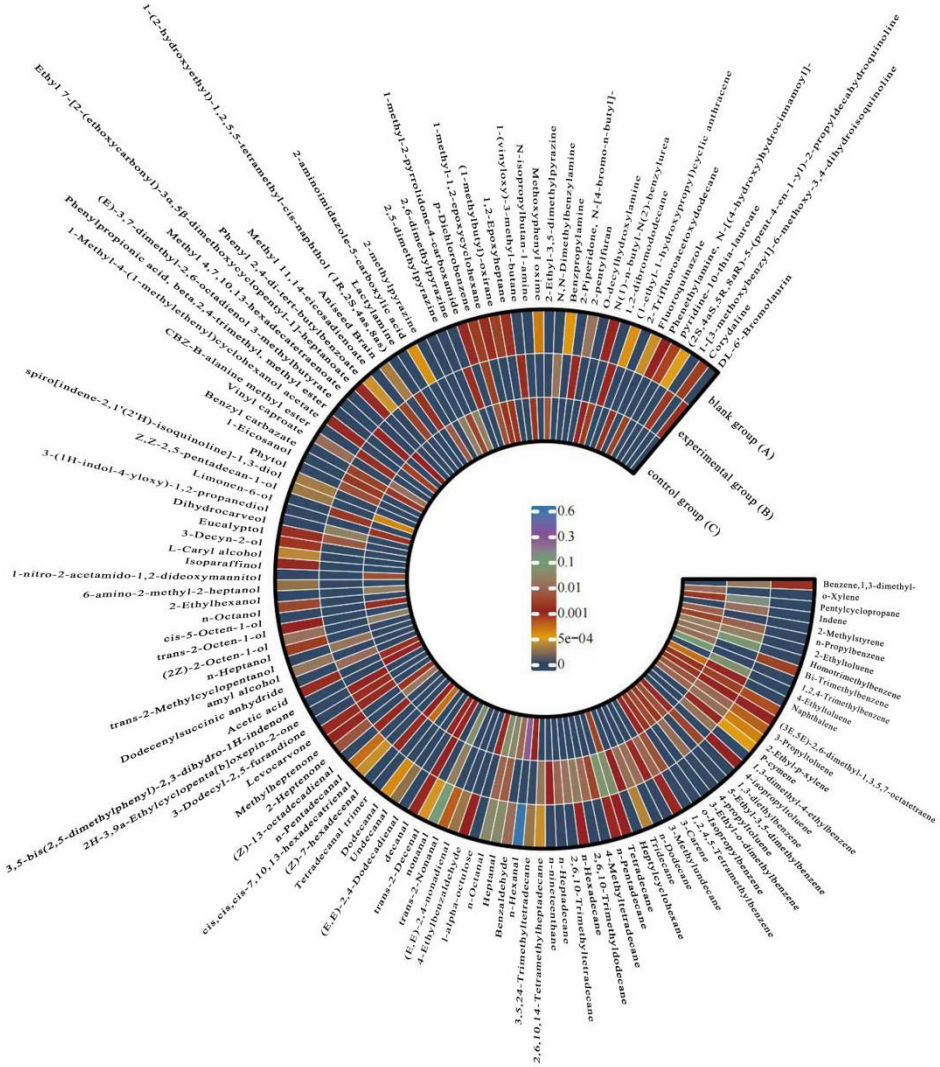


Figure 3-9. Heat map of the volatile flavor components of beef

Hydrocarbon compounds are late products of oxidation of meat amino acids and fats[20].The hydrocarbons in their volatile components include both saturated and unsaturated hydrocarbons. Saturated hydrocarbons are mainly produced by alkoxy homolytic reactions and are considered to play a less significant role in the development of meat flavor and odor due to their higher threshold values[21].The unsaturated hydrocarbons, which mainly include two major categories of aromatic hydrocarbons and olefins, have low flavor thresholds and strong odors, which have a greater impact on the flavor and give the product a unique aroma. A total of 40 hydrocarbons were detected in the three beef samples, of which 15 hydrocarbons were measured in group A with a content of 1.956%, 30 hydrocarbons were measured in group B with a content of 77.711%, and 21 hydrocarbons were detected in group C with a content of 25.494%.The lowest content was detected in group A, which may be due to the fact that the fresh meat was directly processed, and the meat freshness fat oxidation is less. Groups B and C were cooked for 21 days for the Volatile compounds were measured in Groups B and C, so significant changes in hydrocarbon compounds occurred in Groups B and C compared with Group A. The hydrocarbon compounds measured in Group B were mainly unsaturated hydrocarbons, including p-xylene, 2-ethyltoluene, bixylene, and 2-methylstyrene, which had a strong aromatic and fruity aroma and a low threshold, and had a greater impact on the flavor and odor of the meat. o-xylene, which has a toluene odor, resulting in the possible poorer flavor formed in Group C.

Aldehydes are formed in meat products mainly by lipid oxidation and Strecker degradation reaction of amino acids[22],which are the main indicators of meat aroma. A total of 19 aldehydes were detected in the three beef samples, of which 19 were measured in group A with a content of 84.231%, 6 aldehydes were measured in group B with a content of 6.051%, and 10 were detected in group C with a content of 47.087%. The relative contents of n-hexanal, nonanal, and heptanal were higher in group A. The relative contents of aldehydes in groups B and C were much lower than those in group A. This could be attributed to the prolongation of the aging time, which Fat oxidation occurs, so that the aldehydes are gradually decomposed or transformed. Groups A and C were dominated in the content of aldehydes final hexanal substance, which has a grassy, fatty aroma in beef, with a low threshold, and has a positive effect on the flavor of beef, but may produce an unpleasant odor, or even stinky smell, at a high concentration [23].Benzaldehyde was measured in Groups A and C, with a relative content of 1.121%, respectively, 0.965%. Benzaldehyde is a tyrosine degradation product[24]and has a bitter almond odor.

Ketones are produced by thermal degradation, Meladic reaction and oxidation of alcohols, and have specific aromas such as burnt, eucalyptus and fatty flavors. Most of the ketone compounds have a high threshold value and contribute little to the overall flavor. A total of 6 ketones were detected in the three types of beef, and 3 ketones were detected in each of the three groups ABC and C. The ketones detected in groups A and C mainly consisted of 2-heptanone and methyl heptenone, which had nutty and buttery aroma, and methyl heptenone had lemongrass aroma, which enhanced the overall flavor of the beef and enriched the aroma of the meat.The relative content of the ketones in group B was the lowest, which may be attributed to the fact that the ketones in group B were not detected in the beef. caused by the lower storage temperature than group C under the same storage time, which is consistent with the conclusion of Wang Xiaozhan et al[25].

The relative content of acid compounds was not large, two kinds were detected in the three beef samples, one in each sample, acetic acid was detected in groups A and C, with unpleasant coconut meat oil odor, both of them are unpleasant characteristic compounds of beef. Dodecenylsuccinic anhydride was detected as an acid compound in the samples of group B, with an unpleasant flavor but less irritation, indicating that the odor of group B samples differed from the other samples.

Alcohols are generally produced by the oxidation of fat in muscle tissue and can give beef a sweet and tangy flavor. A total of 21 alcohols were detected in the three samples, of which 12 were measured in group A with a relative content of 6.022%, 6 in group B with a relative content of 8.932%, and 6 in group C with a relative content of 9.095%. Most of the detected alcohols were saturated alcohols with high thresholds, which had less effect on the flavor of the steaks. The saturated alcohols of C7-C10 had an aromatic odor, and with a further increase in the carbon number, the odor of the saturated alcohols gradually diminished to anosmia [26].

Esters are mainly generated through esterification reaction, generally C1 ~ C10 esters have fruit flavor, and long-chain esters have greasy flavor[27]. A total of 12 esters were detected in the three samples, of which 4 were measured in group A with a relative content of 1.550%, 4 were measured in group B with a relative content of 1.406%, and 4 alcohols were measured in group C with a relative content of 2.099%. Because of their higher threshold, their contribution to the aroma was less than that of aldehydes, which could enrich the overall aroma. The decoction process volatilized or degraded the esters, leading to a decrease in the content at the later stage.

Ethers and phenolic compounds were detected in smaller relative amounts and categories. Aniseed brain, an ether with aniseed and sweet flavors, has a harmonizing effect on steak flavor, probably due to high volatilization during aging and frying, and thus was detected in both BC groups.

Heterocyclic compounds mainly originated from the melad reaction and amino acid degradation, mostly with meat flavor, mainly including furan, pyrazine and thiazole. A total of 12 ester compounds were detected in the three samples, of which 16 were measured in group A, with a relative content of 4.896%; 8 were measured in group B, with a relative content of 4.349%; and 13 alcohols were measured in group C, with a relative content of 13.320%. Although the measured levels were low, they play a crucial role in the formation of the overall aroma as the threshold is usually low. 2-n-pentylfuran, which is mainly derived from the oxidative degradation of linoleic acid, has a greenish, meaty aroma, and is often considered to be an important contributor to the flavor of meat. Pyrazines are derived from the Strecker degradation of amino acids, dicarbonyl compounds, and the condensation of aminocarbonyl compounds, and have typical meaty, roasted, and nutty aromas. Furan compounds have typical meaty, roasted, and charred aromas[28]and generally have a lower threshold value, contributing more to the overall aroma of beef. Thiazoles were not detected in the three meat samples selected for this study, which may be caused by the fact that the thiazole content was below the detection limit of the instrument.

3.7.3. Analysis of volatile flavor components of beef

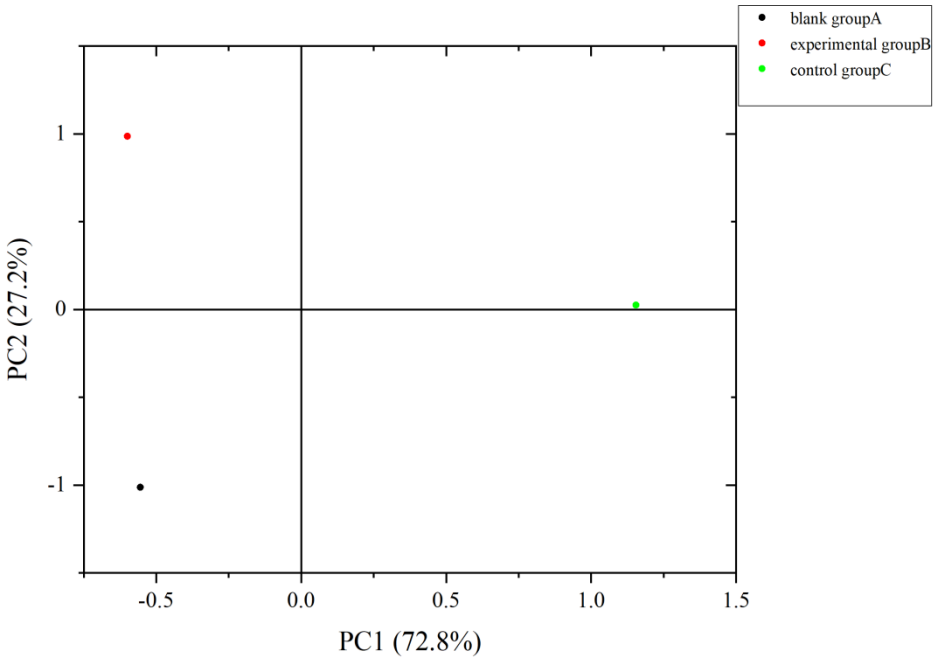


Figure 3 -10. The principal component score plot

Principal Component Analysis (PCA) is a method used for data downscaling and feature extraction, which utilizes

dimensionality reduction thinking to transform multiple metrics into a small number of composite metrics. Referring to the method of Teng Xinlei [29]with slight modifications, 15 volatile components screened by using components with relative content higher than 2% and OAV values were subjected to principal component analysis. In this study, the 25 volatile components jointly contained in the beef of the blank group (A), experimental group (B), and control group (C) were subjected to principal component analysis, and the resulting principal component score plots are shown in Fig. 3-9, the resulting principal component loading plots are shown in Fig. 3-10 and Fig. 3-11, and the eigenvalues and cumulative contributions of the resulting correlation matrices are shown in Table 3-6, and the resulting principal component loading matrices and eigenvectors are shown in Table 3-7.In order to more intuitively reflect the proportion of various compounds in each principal component, the points on the three-dimensional loading diagram (Figure 3-12) were projected onto the plane to obtain a two-dimensional loading diagram (Figure 3-11).

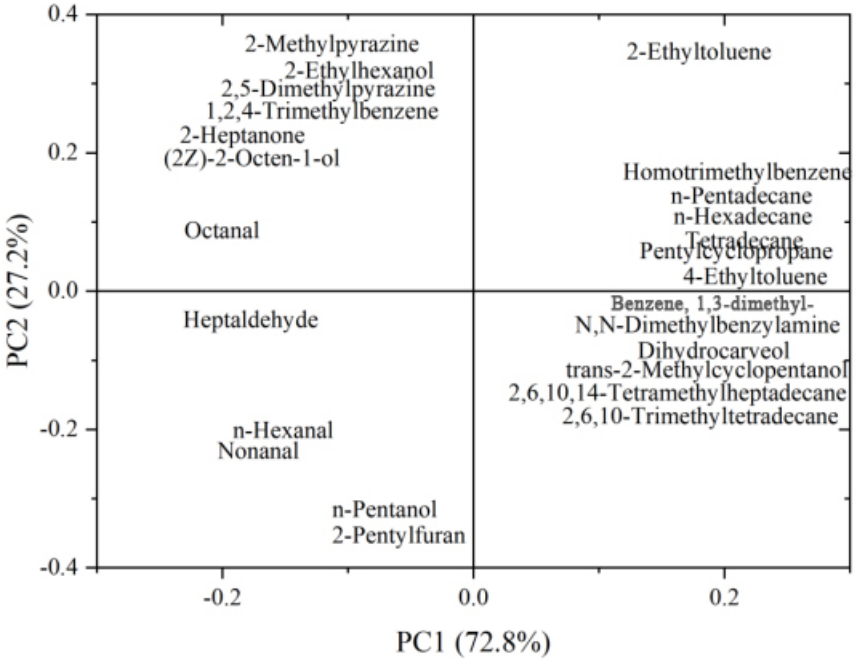


Figure 3-11. Two-dimensional loading plot of principal components

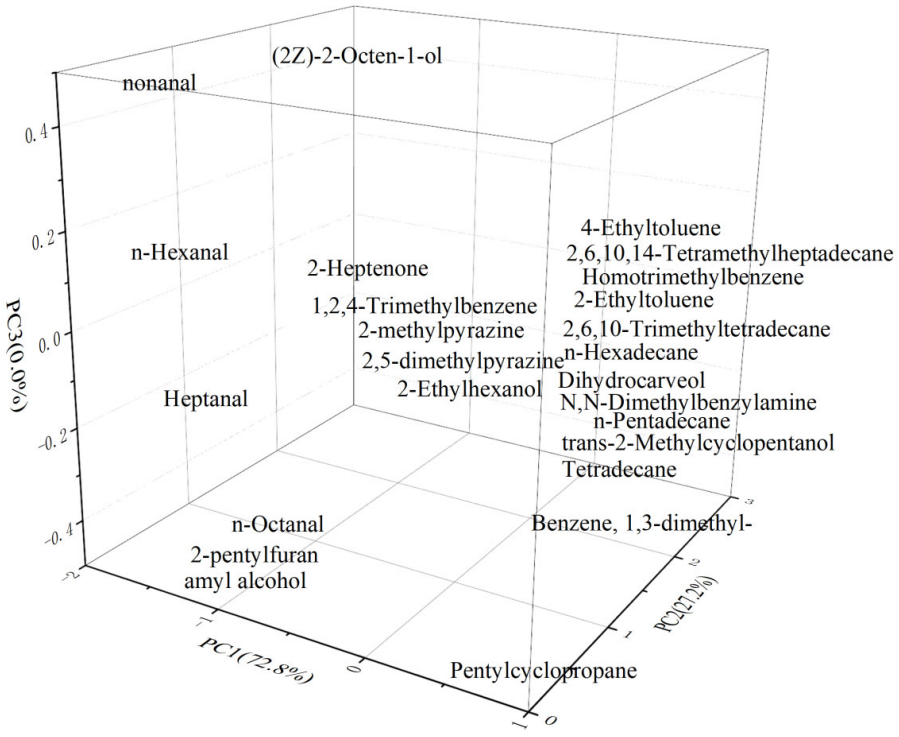


Figure 3-12. Three-dimensional loading diagram of principal components

Table 3-6. Eigenvalues and Cumulative Contributions of the Correlation Matrix

principal component	characteristic value	Contribution rate / %	Cumulative contribution rate / %
1	18.19762	72.79046	72.79046
2	6.80238	27.20954	100
3	5.90626E-31	2.3625E-30	100

Table 3-7. Principal component load matrix and eigenvectors

volatile constituent		PC1		PC2		PC3	
order number	name	payload	eigenvector	payload	eigenvector	payload	eigenvector
X1	Xylene	0.234	1.15234	-0.02298	-0.06919	-0.09685	-0.13035
X2	Pentylcyclopropane	0.23422	1.15342	0.01594	0.04801	-0.60667	-0.8165
X3	2-Ethyltoluene	0.1221	0.60129	0.3273	0.9857	0.02811	0.03784
X4	Homotrimethylbenzene	0.21959	1.08139	0.13421	0.40418	0.12766	0.17181
X5	1,2,4-Trimethylbenzene	-0.12168	-0.59923	0.32772	0.98696	0.00563	0.00757
X6	4-Ethyltoluene	0.23436	1.15414	0.0085	0.02559	0.18527	0.24934
X7	Tetradecane	0.23377	1.15123	0.02847	0.08574	-0.04155	-0.05592
X8	n-Pentadecane	0.23442	1.15442	8.08E-04	0.00243	0.10455	0.14071
X9	n-Hexadecane	0.23442	1.15441	-0.00158	-0.00475	0.10372	0.13959
X10	2,6,10-Trimethyltetradecane	0.23436	1.15414	0.0085	0.02559	0.10726	0.14436
X11	2,6,10,14-Tetramethylheptadecane	0.23441	1.15439	0.00288	0.00868	0.18328	0.24668
X12	n-Hexanal	-0.19194	-0.94521	-0.22012	-0.66293	0.1924	0.25894
X13	Heptaldehyde	-0.23155	-1.14027	-0.05984	-0.18021	-0.04828	-0.06498
X14	Octanal	-0.23058	-1.13549	0.06914	0.20823	-0.27661	-0.37228
X15	Nonanal	-0.18463	-0.90923	-0.23625	-0.7115	0.39846	0.53627
X16	2-Heptanone	-0.17712	-0.87223	0.25117	0.75643	0.07834	0.10544
X17	n-Pentanol	-0.11268	-0.55491	-0.33621	-1.01255	-0.15189	-0.20442
X18	trans-2-Methylcyclopentanol	0.23436	1.15414	0.0085	0.02559	0.06825	0.09186
X19	(2Z)-2-Octen-1-ol	-0.19859	-0.97795	0.20374	0.61358	0.38211	0.51427
X20	2-Ethylhexanol	-0.12168	-0.59923	0.32772	0.98696	-0.07238	-0.09742
X21	Dihydrocarveol	0.23436	1.15414	0.0085	0.02559	0.06825	0.09186
X22	2-Methylpyrazine	-0.12168	-0.59923	0.32772	0.98696	-0.07238	-0.09742
X23	2,5-Dimethylpyrazine	-0.12168	-0.59923	0.32772	0.98696	-0.07238	-0.09742
X24	N,N-Dimethylbenzylamine	0.23436	1.15414	0.0085	0.02559	0.06825	0.09186
X25	2-Pentylfuran	-0.11268	-0.55491	-0.33621	-1.01255	-0.15189	-0.20442

From Table 3-6 and can be seen, the cumulative contribution rate of the 1st principal component and the 2nd principal component reaches 100%, according to the principle of principal component analysis generally extracted principal components contain more than 80% of the information, the first 2 principal components can basically explain the vast majority of the information of the original 25 variables. The contribution rate of the 1st principal component reaches 72.79046%, and the contribution rate of the 2nd principal component is 27.20954%, which indicates that the data after principal component dimensionality reduction can reflect the overall information of the original data.

As shown in Table 3-7, the indicators reflected by the 1st principal component are n-pentadecane, n-hexadecane, 2,6,10,14-tetramethylheptadecane, 4-ethyltoluene, 2,6,10-trimethyltetradecane, trans-2-methylcyclopentanol, dihydrocarvone alcohol, N,N-dimethylbenzylamine, pentyl cyclopropane, xylenol, tetradecane, homotrimethylbenzene, 2-ethyltoluene and are related to n-pentanol, 2-n-pentyl furan, 1,2,4-trimethylbenzene, 2-ethylhexanol, 2-methylpyrazine, 2,5-dimethylpyrazine, 2-heptanone, nonanal, n-hexanal, (2Z)-2-octen-1-ol, n-octanal, and heptanal were negatively correlated. From Table 3-5 and Table 3-7, it can be seen that the proportion of alkanes in the 1st principal component is higher, mainly because of their higher relative content, the actual aroma role is smaller, so for the 1st principal component contributes more to furans, aldehydes, and alcohols, but these volatile components are negatively correlated with flavor, combined with the content of each part of the volatile components in Table 2-4, it can be initially considered that these negatively correlated components contribute more to the flavor of It can be concluded that these negatively correlated components contribute more to the flavor of beef.

N-dimethylbenzylamine, 2, 6, 10, 14-tetramethylheptadecane, n-pentadecane, and was negatively correlated with n-hexadecane, xylene, heptanal, n-hexanal, nonanal, n-pentanol, and 2-n-pentylfuran. Pyrazines and alcohols were predominant in the second principal component, mainly because their relative contents were lower than aldehydes and hydrocarbons, higher than other classes of compounds, and with lower thresholds, they contributed more to beef flavor.

The cumulative contribution of the first 2 principal components reached 100%, and the linear regression equations of the first 2 principal components PC1, PC2 were established:

PC1:Y1=1.15234X1 +1.15342X2 +0.60129X3+ 1.08139X4 -0.59923X5 +1.15414X6 +1.15123X7 +1.15442X8 +1.15441X9 +1.15414X10 +1.15439X11 -0.94521X12 -1.14027X13 -1.13549X14 -0.90923X15 -0.87223X16 -0.55491X17 +1.15414X18 -0.97795X19 -

0.59923X20 +1.15414X21 -0.59923X22 -0.59923X23 +1.15414X24 -0.55491X25

PC2:Y2=-0.06919X1 +0.04801X2 +0.9857X3 +0.40418X4 +0.98696X5 +0.02559X6 +0.08574X7 +0.00243X8 -0.00475X9 +0.02559X10 +0.00868X11 -0.66293X12 -0.18021X13 +0.20823X14 -0.7115X15 +0.75643X16 -1.01255X17 +0.02559X18 +0.61358X19 +0.98696X20 +0.02559X21 +0.98696X22 +0.98696X23 +0.02559X24 -1.01255X25

Where X1~X25 are the standardized transformed standard variables, and each coefficient is the eigenvector of each substance.

After the calculation of Y=0.7279046Y1+0.2720954Y2, the comprehensive score of each sample can be obtained Y. The coefficients are the contribution rate of each principal component, and Y1~Y2 are the scores of each principal component.

Table 3-8. Comprehensive scores and rankings of three kinds of beef

category	Comprehensive score(Y)	ranking
blank group (A)	-4.468247841	3
experimental group (B)	4.070973681	1
control group (C)	0.39726596	2

4. Conclusions

In this study, the raw material of unfrying Simmental crossbred yellow beef was used as raw material. Firstly, the optimal combination of the raw meat after pre-treatment ripening was obtained through one-way and orthogonal experiments as ripening time of 21 days, ripening temperature of 2°C and air flow rate of 2 m/s, which was determined as the optimal process for beef dry-type ripening (experimental group B). Secondly, the raw meat after ripening in the blank group (A), experimental group (B), and control group (C) were pan-fried to obtain pan-fried beef, respectively. Focusing on the fried beef of groups B and C, the moisture content, FTIR and volatile substances determined by solid-phase microextraction (SPME)-gas chromatography-mass spectrometry (GC-MS) were compared to determine the optimal process for frying dry-aged meat.

Based on ATR-FTIR and SPME-GC-MS techniques, the flavor and moisture differences produced by frying beef in different dry-aging conditions were thoroughly investigated. It was found that different dry maturation conditions had differences in flavor formation and moisture. The pH value and color difference of beef changed with maturation time, and these changes were closely related to flavor formation. The experimental results showed that with the maturation time of 21 days, the physicochemical indexes, such as pH and color difference, showed significant changes in Groups B and C. By SPME-GC-MS technique, a total of 131 volatile flavor constituents were identified, including 40 hydrocarbons, 21 alcohols, 19 aldehydes, 6 ketones, 1 phenol, 10 esters, 2 acids, 1 ether, and 31 heterocyclic and other analogous compound classes. Through principal component analysis, flavor heat map and linear regression equation, the results showed that the beef in group B had the highest overall score, indicating that the group had the best flavor. The flavor suitability evaluation method established in this study can obviously compare the differences in volatile substances and relative contents between Groups A, B and C, and provide a theoretical basis for the flavor control of dry-aged beef.

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