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Preservation Effect of Different Freezing Treatment on the Braised Beef Prefabricated Dishes

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ABSTRACT

This thesis takes the braised beef meal kit as the experimental object, selects two freezing methods of refrigerator (-18℃) and liquid frozen sleep (-25℃) for processing and then stores it in the refrigerator (-18℃) for 30 days, aiming to study the preservation effect of liquid frozen sleep technology on prefabricated dishes under frozen storage conditions. Taking cold storage (4℃) as the blank, the changes of texture, color, water content, sensory quality, protein structure and volatile components of braised beef were determined on the 10th, 20th and 30th days. The main research conclusions are as follows: In terms of texture, the hardness, chewiness and elasticity of beef all show a downward trend during storage, and the range of the frozen sleep group is lower than that of the refrigerator group; in terms of color, the L* value shows a trend of first increasing and then decreasing during storage, and the a* and b* values show a downward trend, among which the changes of the frozen sleep group are all smaller than those of the refrigerator group; in terms of water content, the water content of beef in the refrigerator group decreased from 67% to 50%, and the water content of beef in the frozen sleep group decreased from 67% to 56%; in terms of the secondary structure of protein, with the extension of storage time, the hydrogen bonds of the highly ordered α-helix structure are broken, and gradually transformed to the disordered β-turn and random coil structure, while the contents of the regular and ordered structures of α-helix and β-fold in the frozen sleep group decrease less than those in the refrigerator group; in terms of volatile components, the content of volatile substances of both freezing methods increases with the extension of storage time, while the content of volatile substance components of the frozen sleep group increases less. Liquid frozen sleep technology can be applied to the storage of braised beef, which can make the meat products maintain better quality in prefabricated dishes.

KEYWORDS

Braised beef cooking package; Storage; Tomin

1. INTRODUCTION

With the acceleration of modern people's pace of life and the transformation of consumption concepts, Prefabricated dishes have ushered in a favorable consumption environment due to their convenient, fast, and delicious characteristics. Consumers' requirements for the quality, freshness, taste, and flavor of Prefabricated dishes are also increasing day by day. Preservation is an important part of the Prefabricated dishes flow process, and improving the preservation effect, or recovery rate, is crucial for the Prefabricated dishes industry [1-2]. Room temperature cooking bag products often face defects such as poor recovery rate and insufficient quality due to structural damage, which limits the development of the Prefabricated dishes industry for room temperature cooking bags. Although traditional freezing preservation techniques have extended the shelf life of food to a certain extent and improved the preservation effect, the formation and growth of ice crystals during the freezing

process often damage the tissue structure of food, resulting in a decrease in the taste, color, and nutritional value of thawed food [3-4]. Rapid freezing can lower the temperature of food to an extremely low level in the shortest possible time, thereby reducing the possibility of large ice crystals formed by internal moisture in the food. During the freezing process, large ice crystals can easily damage the cellular structure of food ingredients, resulting in a loose texture and poorer taste after thawing. The tiny ice crystals formed by rapid freezing can better maintain the cellular integrity of ingredients, thus preserving their original texture and taste after thawing.

Tomin technology is a new type of food rapid freezing treatment technology that uses ethanol as a refrigerant. It has many advantages: (1) It has a fast freezing speed, which is 20 times faster than ordinary freezing and 8 times faster than liquid nitrogen freezing; (2) The volume of ice crystals formed is small, and the ice crystals formed by the water inside the food cells after freezing and sleeping treatment are only five microns in size, which will not cause physical damage to the cell membrane and cell wall. After thawing, the food can maintain its original flavor to the greatest extent possible. The operating cost is almost the same as that of ordinary freezing methods, and compared to volatile liquid nitrogen, the operating cost can be reduced by about 80%. Frozen bamboo pod fish sashimi products can be preserved for more than a year in a -18 ℃ environment using frozen sleep technology. After natural thawing, the inherent juice, nutrients, and freshness substances of the ingredients will not be lost. The color is bright, and the freshness remains the same [5]. Moriya's research shows that frozen bamboo pod fish sashimi products treated with frozen sleep can significantly improve the freshness of the product. The quality of the product after thawing is not significantly different from that of fresh fish meat within 14 hours [6]. The research conclusion of OHNISHI et al. also showed that within 1-3 days, the fracture curve of olive meat treated with liquid freezing sleep was like that of meat stored at 4 ℃, indicating that the structure of olive flounder muscle was well preserved [7]. From this, the application of liquid freezing sleep technology can maximize the freshness and taste of premade vegetables and help promote the development of the premade vegetable industry, ensure product quality, enhance market competitiveness, and create better economic benefits. However, due to the fact that the equipment and technology are sourced from Japan, most of the preliminary research has focused on premade dishes or meat products in Japan, and there is relatively little research on the preservation effect of domestic products.

The aim of this study is to explore the specific impact of liquid freezing sleep technology on the preservation effect of braised beef meal packs. Through experimental data and analysis, it provides strong theoretical support and practical guidance for the application of liquid freezing sleep technology in the preservation of Chinese premade dishes.

2. MATERIALS AND METHODS

2.1. Material and Reagents

The raw material used in this experiment is beef stored at -18 ℃.

Salt, sugar, Baijiu, beer, monosodium glutamate, star anise, cinnamon, cumin, Chinese prickly ash, cloves, licorice, soy sauce, vanilla, food grade.

2.2. Equipment and Instruments

HC2003 electronic analytical balance, Cixi Huaxi Weighing Instrument Industrial Co., Ltd; TAXT PlusC UK SMS texture analyzer, Stable Micro Systems, UK; C21-WT2121 Induction Cooker, Guangdong Midea Household Electrical Appliance Manufacturing Co., Ltd; BCD-471WDCD refrigerator, Qingdao Haier Co., Ltd; ATR-iD7 Fourier Transform Infrared, Zhejiang Chint Electric Co., Ltd; SC-10 colorimeter, Shenzhen San'enshi Technology Co., Ltd; DHP-420 electric constant temperature incubator, Tianjin Zhonghuan Experimental Electric Furnace Co., Ltd; DC-3010 self-

developed liquid freezing sleep equipment (using ethanol as the refrigerant), Changzhou Guowang Instrument Manufacturing Co., Ltd; 7890A-5975C gas chromatography-mass spectrometry analyzer, Agilent Technologies (China) Co., Ltd.

2.3. Method

2.3.1. The production of braised beef

Thaw and clean the beef that has passed the inspection in a bag in water at room temperature, cut it into uniform pieces of 2cm × 2cm × 1cm, add auxiliary materials and mix well. Marinate it at room temperature, then steam it in a pot, take it out and cool it to room temperature for later use.

2.3.2. Freezing treatment of braised beef

The processed braised beef is randomly divided into two equal parts. One part is frozen to -25 ℃ in a low-temperature constant temperature water bath using a self-developed liquid freezing and sleeping equipment, and then stored in a -18 ℃ refrigerator for 30 days, labeled as Frozen Sleep Group (FG). The other part is stored in a -18 ℃ refrigerator for 30 days, labeled as Ordinary Freezing Group (OG). At the 10th, 20th, and 30th day, physical and chemical indicators such as texture characteristics, color difference, moisture content, and protein secondary structure were measured for the two groups, respectively [3].

2.3.3. Texture determination of braised beef

Texture analyzer is often used for food physics testing and has long been recognized by many food testing personnel due to its high sensitivity and objectivity [8-9]. Referring to the method of Zhao Jiayi et al. [10] and making modifications, beef was reheated in a water bath, cooled to room temperature, and then cut into regular shapes of 20mm × 20mm × 10mm for measurement. The measurement parameters were as follows: probe type was P36R, pre-test rate, test rate, and post-test rate were all 2.0mm/s, sample strain was 40%, initiation force was 5g, and the recovery time of the intermediate cycle was 5s. Select three parameters of hardness, elasticity, and chewiness as analysis indicators, and repeat parallel experiments three times for each group of samples.

2.3.4. Determination of color of braised beef

Refer to the research methods of Wang Ying [11], Liu Shan [12] and others. After reheating the braised beef in a water bath, cool it to room temperature, wipe off the surface juice, place the sample in the reflection area of the colorimeter (1 cm) to completely cover it, and measure the L *, a *, and b * values of the beef surface and center separately. Each sample needs to be measured in parallel at least 3 times.

2.3.5. Determination of moisture content in braised beef

The determination of moisture content shall refer to the direct drying method in the national standard GB 5009.3-2016 [13].

2.3.6. Fourier transform infrared determination of braised beef

The sample cooled to room temperature after reheating in a water bath is dried in a 40 ℃ oven, ground into powder using a mortar, sieved through a 200 mesh sieve, and collected for later use. According to the method of Qingsen L et al. [14], take an appropriate amount of the above powder and place it on an ATR attachment for scanning. At the same time, use OMNIC software to record the infrared spectrum with a scanning range of 4000~400cm-1, scan 32 times, and scan with a resolution of 4cm-1. Use OMNIC and peakfit4.12 for data processing.

2.3.7. Sensory evaluation of braised beef

Referring to the method of Wang Ying et al. [11], modifications were made based on the actual situation, and a sensory evaluation group consisting of 10 food majors was selected to conduct

sensory evaluation on braised beef samples. After the sample is subjected to water bath reheating treatment, it is immediately randomly divided into the same disposable cup, encoded with a random three-digit number, and rinsed with water when tasting different samples. Sensory evaluation and scoring are conducted on the color, texture, aroma, taste, and overall acceptability of beef. The lower the sensory score of the sample, the worse the sensory quality of the sample, with a total score of 100 points. The specific sensory evaluation criteria are shown in Table 1.

Table 1. Table1Braised beef sensory scoring criteria

project	evaluation criterion	score
color and lustre	Good color, glossy, uniform and consistent	14-20
	Good color, insufficient glossiness, basically uniform and consistent	7-13
	Poor color, no luster, poor uniformity and consistency	0-6
texture	The meat is tight and elastic	14-20
	The meat is tight and elastic	7-13
	Loose meat texture with poor elasticity	0-6
smell	Rich aroma without any unpleasant odors	14-20
	Moderate fragrance, no unpleasant odor	7-13
	The fragrance is light and there is a strange odor	0-6
taste	Refreshing taste, juicy, easy to chew	14-20
	Good meat quality, easy to chew and loose, with less juice	7-13
	The meat is hard, difficult to chew, and lacks juice	0-6
Overall acceptability	Very ideal	14-20
	More ideal	7-13
	Very unsatisfactory	0-6

2.3.8. Determination of volatile flavor compounds in braised beef

GC conditions: The chromatographic column is Agilent HP-5MS (30m × 250 μ m × 0.25 μ m), the carrier gas is helium gas, the flow rate is 1.78mL/min, the pressure is 13.953psi, the purge flow rate is 3ml/min, the injection port and transmission line temperature are 250 ℃, and the heating program: starting temperature is 35 ℃, hold for 1 minute, then rise to 100 ℃ at 10 ℃/min and hold for 3 minutes, then rise to 120 ℃ at 4 ℃/min and hold for 2 minutes, then rise to 200 ℃ at 6 ℃/min and hold for 3 minutes, and finally rise to 220 ℃ at 8 ℃/min and hold for 2 minutes. Split injection is performed with a split ratio of 2:1 and a retention time of 1 minute.

MS conditions: Electron bombardment (EI) ion source energy of 70eV, ion source temperature of 230 ℃, transmission line temperature of 250 ℃, mass scanning range of m/z 35~500.

2.3.9. Data processing

Perform protein secondary structure data analysis and processing using OMNIC and peakfit4.12. SPSS was used for data significance analysis, and Origin 2021 was used for data plotting.

3. RESULTS AND ANALYSIS

3.1. The Influence of Different Storage Methods on the Texture Characteristics of Braised Beef

Texture characteristics are important indicators for measuring the quality of meat products. The effects of different storage methods on the texture characteristics of braised beef are shown in Table 2. According to Table 2, the hardness of OG and FG meat samples showed a decreasing trend during storage, which may be due to the fact that the hardness is mainly related to the moisture content of the product. The decrease in moisture content leads to a decrease in hardness. When reheating the

sample, high temperature also affects the texture of the product, resulting in a decrease in hardness of the meat sample [15]. The hardness of FG is higher than that of OG at 10d, 20d, and 30d. On the 10th day, the hardness of FG is 2288.89 g and the hardness of OG is 1983.73 g; On the 20th day, the FG hardness was 2014.77 g and the OG hardness was 1920.70 g; On the 30th day, the FG hardness was 1770.01g and the OG hardness was 1680.98g, which may be due to FG freezing the product quickly, producing small ice crystals, causing minimal damage to cells, and having good water holding capacity. In addition, rapid freezing can also inhibit the growth and reproduction rate of microorganisms, thereby maintaining the hardness of the sample. It can be seen that freezing sleep treatment has a better effect on maintaining the hardness of braised beef.

Elasticity refers to the ability of beef to return to its original state after being squeezed, reflecting the freshness and compactness of the meat. Generally, elasticity decreases with prolonged storage time [16]. According to Table 2, the elasticity of both groups of meat samples gradually decreased within the first 30 days of storage, which is consistent with the study by Fu Li et al. [17]. This may be due to changes in the three-dimensional structure of denatured proteins affecting the binding ability of myofibrillar proteins, leading to a decrease in elasticity. FG showed higher elasticity than OG on the 10th, 20th, and 30th days, indicating that frozen sleep treatment has a significant effect on maintaining the elasticity of braised beef.

Chewing ability can reflect the tenderness of a sample, which is related to hardness and elasticity, and is a comprehensive indicator for evaluating texture [18]. According to Table 2, the chewiness of both groups of meat samples showed a decreasing trend during storage. The chewiness of meat samples in FG was higher than that in OG on the 10th, 20th, and 30th days of storage, indicating that frozen sleep treatment has a significant effect on maintaining the chewiness of braised beef.

Table 2. Effects of different storage methods on the texture of braised beef with the extension of storage time

Storage method	Hardness g	Elastic %	Chewiness g
fresh	3141.77±40.85 ^{a}	94.80±1.42 ^{a}	1637.59±20.48 ^{a}
cold storage	2607.24±76.13 ^{b}	98.18±3.59 ^{ab}	1411.62±26.10 ^{b}
10d FG	2288.89±24.29 ^{c}	87.50±1.49 ^{bc}	1396.32±35.46 ^{b}
10d OG	1983.73±26.09 ^{d}	92.22±1.73 ^{cd}	1363.65±98.49 ^{b}
20d FG	2014.77±88.08 ^{d}	84.30±0.71 ^{d}	1329.04±237.43 ^{b}
20d OG	1920.70±76.29 ^{d}	86.19±0.22 ^{d}	1305.50±185.97 ^{b}
30d FG	1770.01±75.84 ^{e}	78.82±1.86 ^{e}	1281.22±7.37 ^{b}
30d OG	1680.98±116.60 ^{e}	68.26±6.23 ^{f}	1076.19±48.76 ^{c}

* Those with the same letters in each column indicate that the difference has not reached a significant level ($P>0.05$), while those with different letters indicate that the difference has reached a significant level ($P<0.05$).

3.2. The Influence of Different Storage Methods on the Color of Braised Beef

The color of beef is one of the most intuitive indicators for identifying beef quality, and it is also an important basis for consumers to choose beef. Braised beef undergoes reactions such as fat oxidation and pigment degradation during storage. The accumulation of free radicals caused by lipid oxidation accelerates the oxidation rate of myoglobin, leading to a decrease in meat color and quality of braised beef, seriously affecting consumers' purchasing desire [19]. The color of braised beef is related to the beef production method, cooking method, storage environment, etc. The effects of different storage methods on the color of braised beef with prolonged storage time are shown in Table 3.

From Table 3, it can be seen that the L * values of beef samples from FG and OG showed a trend of first increasing and then decreasing during storage, and FG increased more slowly than OG, which is

consistent with the study by Yuan Xianqun et al. [20]. The increase in L * value may be due to the leakage of water from beef during storage, the leakage of internal nutrients, the increase in surface moisture content, the increase in surface light reflection, and the increase in brightness value; The decrease in L * value after 20 days may be due to the degradation of product quality under the action of microorganisms, which weakens the reflection of light and leads to a decrease in L * value [21].

During storage, both groups of beef samples showed a decreasing trend in a * value with the prolongation of time, but the OG group showed a significantly accelerated decrease in a * value after 10 days, while the FG group showed a slow decrease. During storage, a * shows a decreasing trend, which may be due to the high temperature during reheating causing water loss in beef, or the Maillard reaction and fat oxidation leading to browning, resulting in a dull overall color of beef. The decrease in beef stored in the refrigerator is even greater, possibly due to the growth and reproduction of microorganisms and the increase in fat oxidation levels during the refrigerator storage process.

During storage, both groups of beef samples showed a decreasing trend in b * values, but at the same storage time, the b * value of FG was higher than that of OG. There are studies indicating that a decrease in a * value represents the loss of red color in meat, and through the formation of high iron myoglobin, its color changes to brownish red, leading to a decrease in b * value [22]. From this, it can be seen that the L *, a *, and b * values of the two sets of beef indicate that compared with ordinary freezing technology, liquid freezing sleep technology has a better effect on slowing down the color change of beef during storage.

Table 3. Effects of different storage methods on the color of braised beef with the extension of storage time

sample	surface			core		
	L*	a*	b*	L*	a*	b*
fresh	37.05±0.01^{a}	10.47±0.10^{a}	33.21±0.12^{a}	42.29±0.09^{a}	10.73±0.14^{a}	25.96±0.43a
1d refrigeration	38.23±0.11^{b}	9.64±0.13^{b}	35.33±0.01^{b}	43.76±0.52^{b}	10.39±0.05^{b}	25.39±0.31ab
10d FG	39.94±0.25^{c}	8.84±0.06^{c}	33.96±0.06^{c}	46.77±0.06^{c}	9.02±0.10^{c}	24.53±0.08bc
10d OG	40.99±0.10^{d}	7.70±0.10^{d}	32.36±0.11^{d}	47.48±0.13^{cd}	8.78±0.13^{d}	23.66±0.07cd
20d FG	43.52±0.64^{e}	8.02±0.01^{e}	31.82±0.05^{e}	43.32±0.14^{d}	8.66±0.09^{d}	22.83±1.47de
20d OG	44.74±0.44^{e}	6.69±0.10^{f}	31.41±0.24^{f}	43.46±0.16^{e}	7.81±0.13^{e}	21.90±0.15ef
30d FG	38.03±0.07^{e}	7.18±0.02^{g}	29.88±0.04^{g}	40.51±0.03^{f}	8.10±0.03^{f}	21.70±0.13f
30d OG	37.89±0.05^{f}	6.50±0.08^{h}	24.62±0.04^{h}	39.84±0.16^{g}	6.71±0.03^{g}	19.38±0.11g

* Those with the same letters in each column indicate that the difference has not reached a significant level (P>0.05), while those with different letters indicate that the difference has reached a significant level (P<0.05).

3.3. Changes in Moisture Content of Braised Beef Stored in Different Ways During Storage

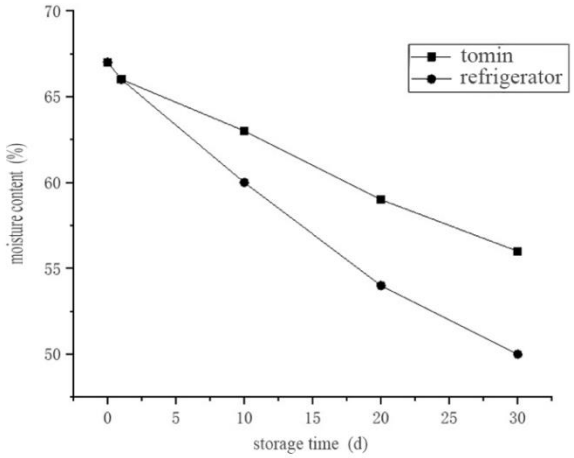

Figure 1. Effect of different storage conditions on water content of beef

The loss of water not only leads to a decrease in the quality of braised beef, but also results in the loss of nutrients in braised beef, and affects qualities such as juiciness, hardness, style, and color. The moisture content of braised beef treated with two different methods varies over time as shown in Figure 1. As shown in the figure, the moisture content of beef in the OG group changed significantly with the extension of storage time, while the change in moisture content of beef in FG over time was smaller than that in OG, consistent with Zhang Ting's study [23]. The moisture content of frozen beef changes significantly with the extension of storage time, which may be due to the sublimation of surface moisture during the freezing process. Under the humidity gradient, there is a humidity difference between the beef and the surrounding air medium, causing the inner layer moisture to migrate to the surface and continue to sublime, resulting in a decrease in moisture content. However, the freezing sleep treatment causes the sample to freeze quickly, generating small and numerous ice crystals, reducing damage to beef cells and minimizing juice outflow. Therefore, freezing sleep technology can effectively delay the decrease in moisture content of braised beef during storage.

3.4. The Effect of Different Storage Methods on the Secondary Structure of Protein In Braised Beef

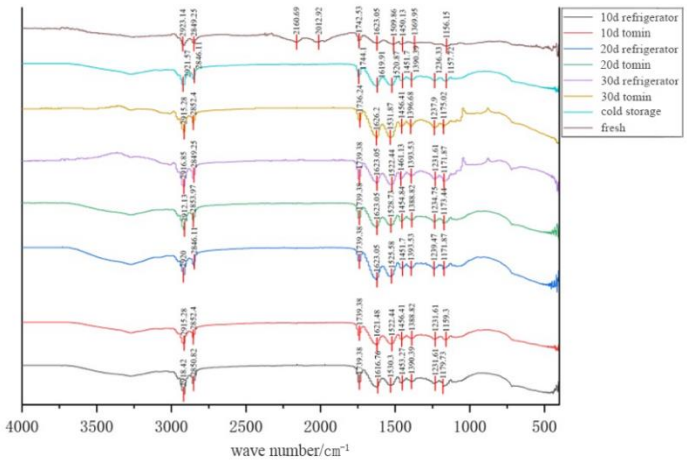

Figure 2. Fourier transform infrared analysis spectrogram

The Fourier transform infrared spectrum of braised beef is shown in Figure 2. After using OMNIC software for automatic smoothing, automatic baseline correction, and other preprocessing of the graph, Fourier automatic convolution was performed on the graph to adjust the peak width to the

highest (<40) and the enhancement to 1.9. CSV format data was exported and analyzed for protein secondary structure content using PeakFit v4.12. The results are shown in Figure 3.

The secondary structure of a protein is a structure formed by the twisting of polypeptide chains through hydrogen bonding, including four types of structures: alpha helix, beta fold, beta turn, and irregular curl. The first two are regular ordered structures, while the latter two are more disordered compared to the first two. Freezing can lead to a decrease in the proportion of alpha helix, beta fold, and beta turn in the secondary structure of beef protein, and an increase in the proportion of irregular curl. From Figure 2 and Figure 3, it can be seen that with the extension of storage time, the proportions of FG and OG α - helix and β - fold decrease, while the proportions of irregular curl and β - turn increase. However, the ordered structures of FG α - helix and β - fold decrease less than OG on the 10th, 20th, and 30th days. Therefore, it can be concluded that the protein denaturation rate of ordinary frozen braised beef increases, and the beef is more prone to spoilage. The secondary structure changes of protein under frozen sleep conditions are more stable, indicating that frozen sleep has a better preservation effect on braised beef. It may be due to the freezing of ice crystals that cause changes in the secondary structure of proteins, a decrease in ordered structure, and the breaking of hydrogen bonds and other forces that maintain protein structure stability [24].

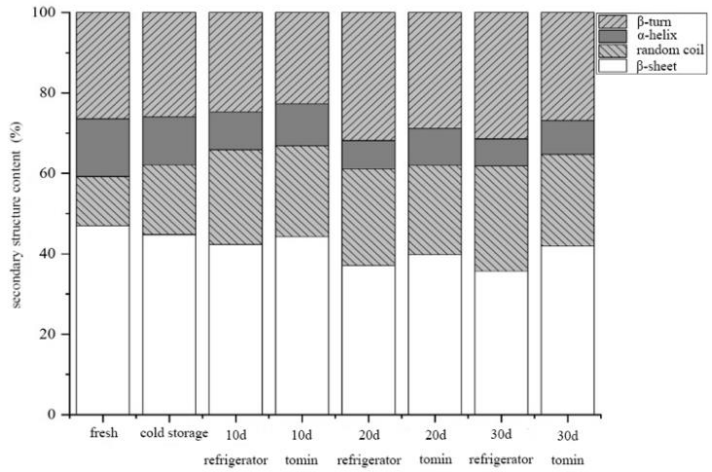

Figure 3. Changes in the content of secondary structure of beef under different storage conditions

3.5. The Influence of Different Storage Methods on the Sensory Perception of Braised Beef

Table 4. Effects of different storage methods on the color of braised beef with the extension of storage time

storage time	color and lustre	texture	Odor	taste	Overall acceptability
fresh	17.6±1.07 ^{a}	17.5±1.27 ^{a}	18.1±0.74 ^{a}	17.8±1.03 ^{a}	17.8±0.63 ^{a}
refrigerate for 1 day	17.4±1,26 ^{a}	17.6±0.97 ^{a}	17.6±0.97 ^{a}	17.2±0.92 ^{a}	17.5±0.85 ^{a}
10d FG	15.4±0.97 ^{b}	14.7±0.95 ^{b}	15.4±1.26 ^{b}	15.3±1.34 ^{b}	14.8±1.03 ^{b}
10d OG	14.7±0.95 ^{bc}	14.4±1.07 ^{bc}	15±1.15 ^{b}	14.8±1.32 ^{b}	14.8±0.79 ^{b}
20d FG	14.3±1.16 ^{c}	13.5±1.08 ^{cd}	12.6±0.84 ^{c}	12.2±1.03 ^{c}	13.2±0.79 ^{c}
20d OG	14.3±1.16 ^{c}	13±0.82 ^{de}	11.7±0.95 ^{cd}	12±0.82 ^{c}	12.5±0.85 ^{cd}
30d FG	12.5±0.85 ^{d}	12.1±1.20 ^{ef}	12.1±0.74 ^{de}	11.6±0.97 ^{c}	12±0.67 ^{de}
30d OG	12.3±0.95 ^{d}	11.7±1.16 ^{g}	11±0.82 ^{e}	11.4±0.97 ^{c}	11.5±0.85 ^{e}

* Those with the same letters in each column indicate that the difference has not reached a significant level ($P>0.05$), while those with different letters indicate that the difference has reached a significant level ($P<0.05$).

Sensory rating is a visual indicator for evaluating the freshness of a product, which directly determines consumers' purchasing desire. The results of the impact of different storage methods on the sensory perception of braised beef are shown in Table 4. According to Table 4, the sensory scores of FG and OG decreased with the extension of storage time throughout the entire storage period, and there was a difference in sensory scores between the two groups but not significant. The sensory score of braised beef in the early storage stage is 88.8 points, with good color, luster, tight and elastic flesh, unique flavor and good taste; After 10 days of storage, the sensory scores of FG were slightly higher than OG, indicating that the freezing sleep technique is more conducive to the preservation of braised beef; At the end of storage, the FG sensory score was 60.3 points and the OG score was 57.9 points. Both groups of beef showed significant browning in color, hardening in texture, and significant loss in taste and texture, basically losing the characteristics of braised beef.

Sensory evaluation can intuitively sense the occurrence of food spoilage, but the evaluation given by sensory evaluators is greatly influenced by personal factors, and each person's sensory sensitivity is different. Therefore, the shelf life of food cannot be determined solely based on sensory evaluation [25].

3.6. The Effect of Different Storage Methods on the Volatile Flavor of Braised Beef

According to solid-phase microextraction gas chromatography-mass spectrometry, the volatile component content of braised beef treated with different freezing methods and different freezing times was measured. A total of 27 volatile components were detected in braised beef treated with freezing sleep and refrigerator, including 7 hydrocarbons, 5 aldehydes, 3 ketones, 7 alcohols, 2 ethers, heterocycles, and 3 other compounds. The total ion flux of volatile components is shown in Figures 4-11, the principal component score is shown in Figure 12, the principal component loading is shown in Figure 13, and the normalized heat map of volatile components is shown in Figure 14.

Hydrocarbons mainly come from lipid decomposition, and most of them have weak or odorless aromas. However, they may serve as precursor substances for the formation of aldehydes, ketones, and flavors, and have potential effects [26-28]. The detected hydrocarbon substances mainly include trimethylbenzene, m-cymene, (+) - limonene, pinene, and 2-methylnaphthalene. Among them, (+) - limonene endows food with citrus and other fruit flavors, mainly derived from star anise and ginger in spices; Aldehydes are particularly important for forming the flavor of meat products, and they show an upward trend during storage, mainly including benzaldehyde, nonanal, and heptanal. Octanal, decanal, and nonanal are oxidation products of oleic acid and are representative flavor compounds in braised beef. Octanal, decanal, and nonanal have a fatty odor, while decanal has a beef fat odor; During the entire storage process, three types of ketones were detected, but their contribution to the overall flavor of braised beef was relatively small; Alcoholic substances mainly include linalool, 1-octen-3-ol, eucalyptol, and alpha terpineol. Linalool, alpha terpineol, eucalyptus oil alcohol, and other flavors that may originate from the heating of ginger can provide aromas similar to floral, nutmeg, and mint, which are closely related to the additives added during the production of braised beef. 1-octen-3-ol, which has a mushroom aroma, is usually considered an oxidized product of arachidonic acid [29-32]; During the storage process, small amounts of ethers and other substances were also detected, mainly including artemether, anethole, and benzothiazole. Fennel brain is the main component of ether compounds, mainly derived from spices such as star anise and fennel added during processing, effectively enhancing the flavor of braised beef. Benzothiazole has a low threshold and contributes significantly to the flavor of meat products.

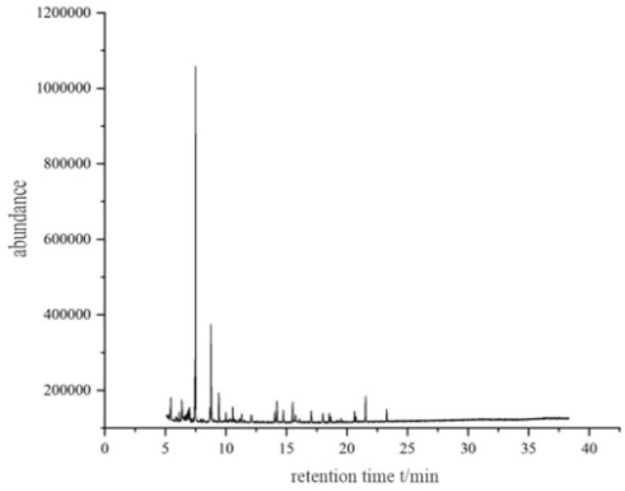

Figure 4. Total ion current chromatogram of fresh braised beef at 0 d. 1 d.

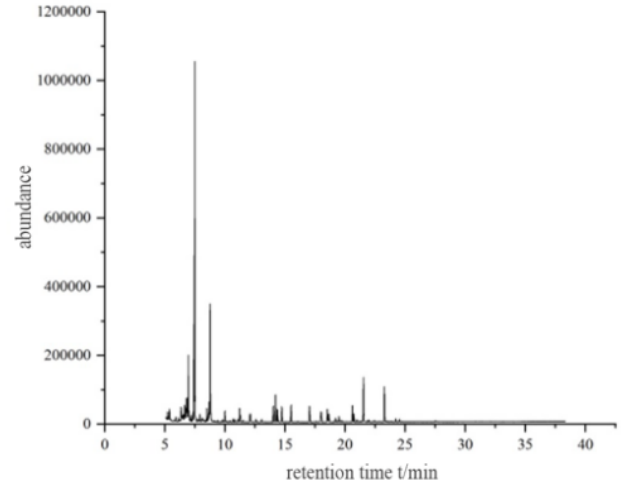

Figure 5. Total ion current chromatogram of cold-stored braised beef at

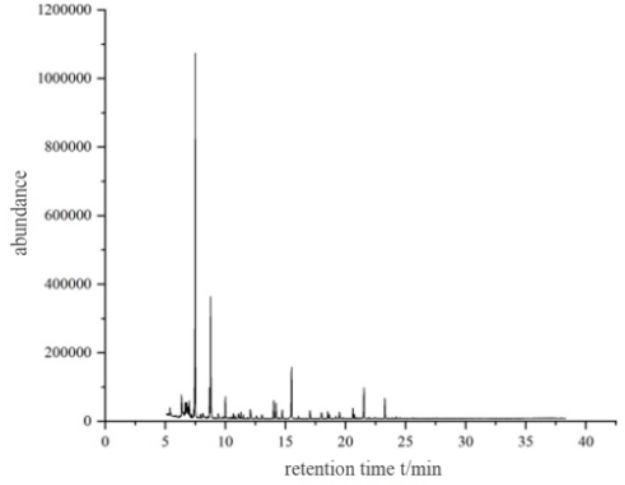

Figure 6. Total ion current chromatogram of freeze-sleep braised beef at 10 d.

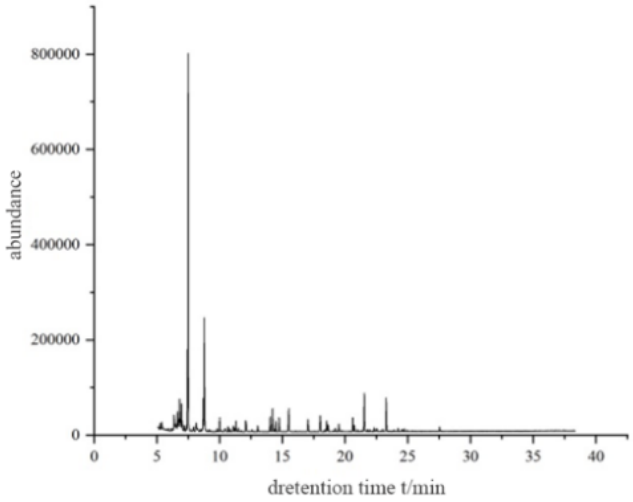

Figure 7. Total ion current chromatogram of braised beef in the refrigerator at 10 d.

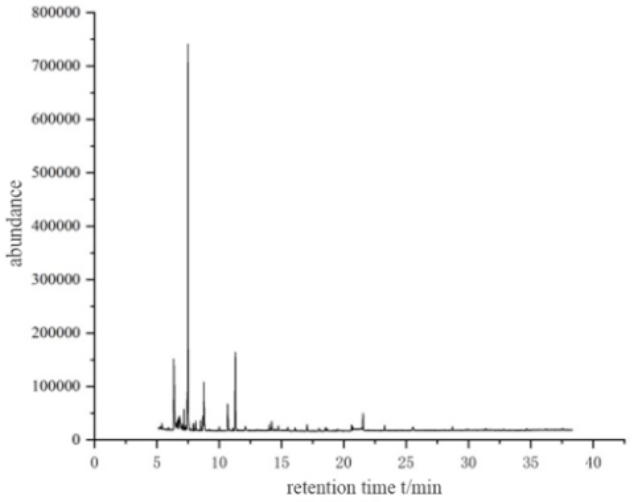

Figure 8. Total ion current chromatogram of freeze-sleep braised beef at 20 d.

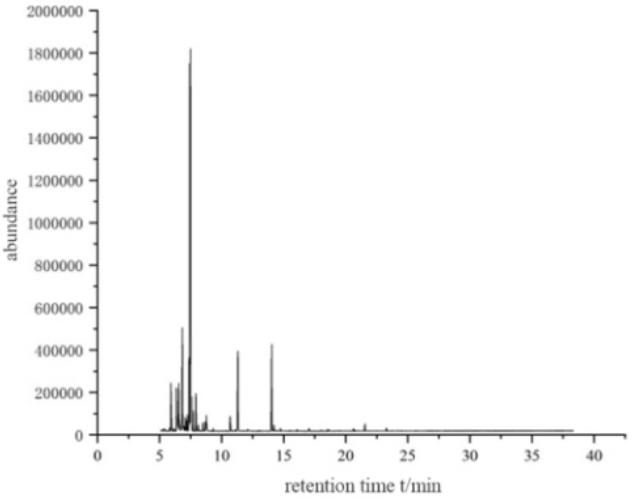

Figure 9. Total ion current chromatogram of braised beef in the refrigerator at 20 d.

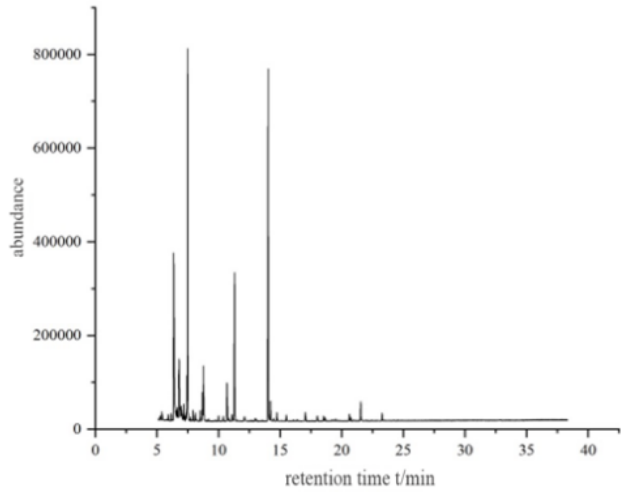

Figure 10. Total ion current chromatogram of freeze-sleep braised beef at 30 d.

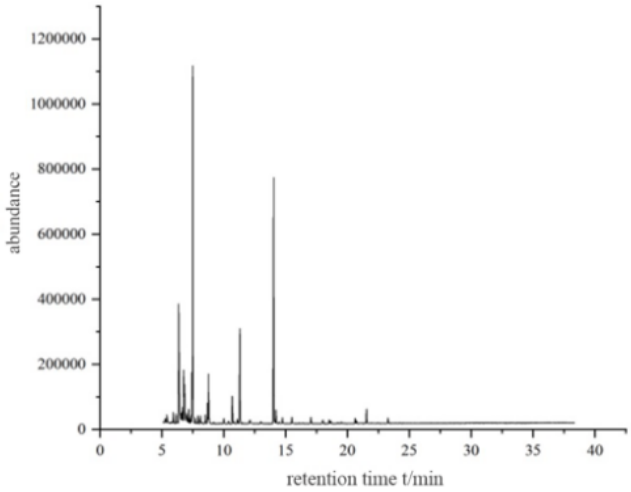

Figure 11. Total ion current chromatogram of braised beef in the refrigerator at 30 d.

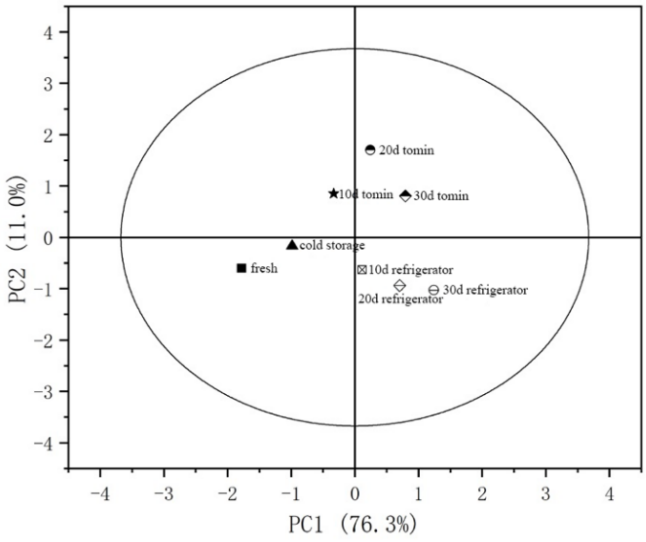

Figure 12. Principal component score map

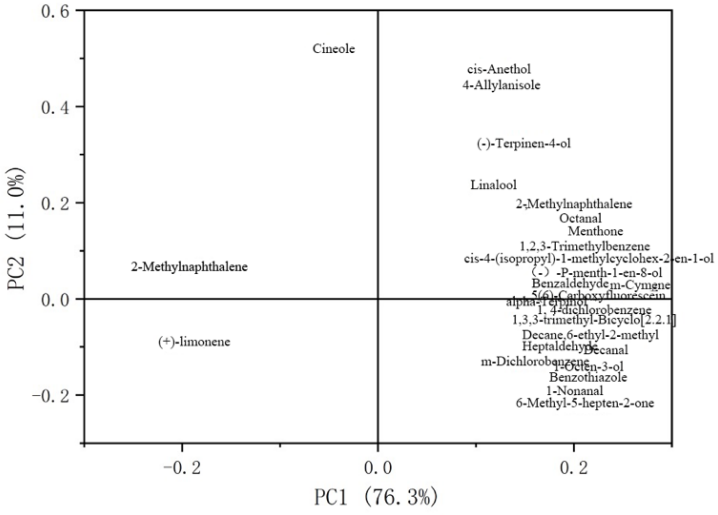

Figure 13. Principal component loading map.

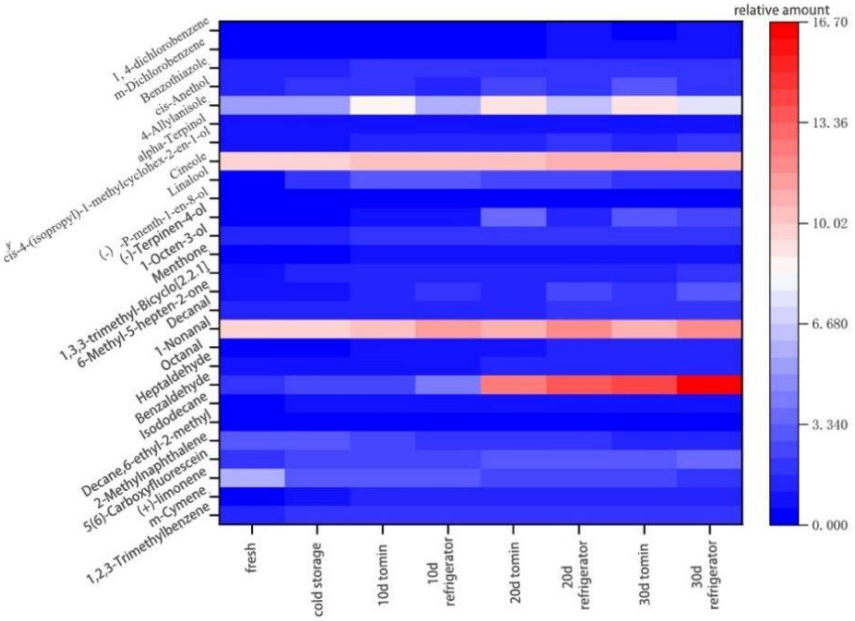

Figure 14. Heat map of relative content of volatile components

4. CONCLUSIONS

This article takes braised beef pre-made dishes as the research object. By comparing the effects of liquid freezing sleep technology and ordinary freezing on the texture, color, moisture content, protein secondary structure, and sensory perception of braised beef during storage, the feasibility of applying liquid freezing sleep technology to braised beef pre-made dishes is judged. In terms of texture, the hardness, elasticity, and chewiness changes of the frozen sleep treated samples were lower than those of the ordinary treated samples; In terms of color, frozen sleep treatment can better preserve the brightness, yellowing, and redness of braised beef products, resulting in better color of the samples; In terms of moisture content, the frozen sleep treated sample beef has a better water retention effect and a relatively slower change in moisture content; In terms of protein secondary structure, with the extension of storage time, the proportion of α - helix and β - fold decreases, while the proportion of irregular curl and β - turn increases. The content of α - helix and β - fold ordered structures in the samples treated in the refrigerator is relatively low, and freezing sleep is beneficial for maintaining

the stability of beef protein secondary structure; In terms of sensory evaluation, both storage methods showed a decrease in the rating of beef over time, but the decrease was smaller in the frozen sleep treated samples, which were more effective in maintaining the flavor and taste of braised beef; In terms of volatile flavor components, the content of substances increases with prolonged storage time, and the frozen sleep treated samples show less change compared to ordinary frozen samples. From this, it can be seen that liquid freezing has a more significant advantage in improving the storage quality of braised beef products compared to ordinary freezing treatment. This discovery has certain reference value for further research on its application in different Chinese cuisine fields.

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REFERENCES

[1] Guo Shuangshuang, Zhu Chun, Liu Hailu, et al. Research progress on quality and safety control technologies for the whole industry chain of precooked meat dishes [J]. Meat Research, 2023, 37 (12): 61-68. DOI:10.7506/rlyj1001-8123-202312009.

[2] Zhou Enchi, Zhang Chunhong, Li Dan, et al. Research and prospect of packaging technology for prepared dishes [J]. Packaging Engineering, 2023, 44(23): 142-147. DOI: 10.19554/j.cnki.1001-3563.2023.23.017.

[3] Hu Rui.Study on quality improvement of typical raw meat based on surface humidity control and physical field synergistic quick freezing/thawing [D]. Wuxi: Jiangnan University, 2023.

[4] Lv Jintao, Shu Yimei, Quan Wei, et al. Changes in color stability of beef during postmortem cold storage and underlying mechanism [J]. Food Science, 2024, 45(14):208-216. DOI: 10.7506/spkx1002-6630-202323023.

[5] Han Yue. Study on the change law of quality of Solenocera crassicornis under different storage temperatures and freezing methods [D]. Zhoushan: Zhejiang Ocean University, 2022.

[6] Keisuke M, Akiko M, Hiroyuki K, et al. Infuence of ice storage period before freezing on quality of frozen chub mackerel Scomber japonicus fllets and considerations. [J] Fisheries Science, 2021, 87: 905–913. DOI:org/10.1007/s12562-021-01552-3.

[7] Ohnishi T, Akuzawa S, Furusawa H, et al. Inactivation of Kudoa septempunctata in Olive Flounder Meat by Liquid Freezing [J]. Biocontrol Science, 2014, 19(3):135-8.DOI:10.4265/bio.19.135.

[8] Yan Yuanyuan. Analysis of the application of texture analyzer in food research [J]. Food Safety Guide, 2016, (06): 56-57. DOI:10.16043/j.cnki.cfs.2016.06.034.

[9] Zhang Qiuhui, Song Lianjun, Huang Xianqing, et al. Implication of texture analyzer in food analysis and detection [J]. Agricultural Product Processing, 2017, (24):52-56. DOI:10.16693/j.cnki.1671-9646(X).2017.12.042.

[10] Zhao Jiayi, Ma Mengbin, Li Yalei, et al. Effect of reheating temperature on texture properties and moisture distribution of sauced beef [J]. Meat Research, 2020, 34 (07): 18-21. DOI:10.7506/rlyj1001-8123-202007004.

[11] Wang Ying, Li Qian, Zhu Yingchun. Comparative analysis of physicochemical properties and sensory quality of beef under different storage conditions [J]. Modern Food Technology, 2022, 38 (02): 119-127. DOI:10.13982/j.mfst.1673-9078.2022.2.0514.

[12] Liu Shan, Wu Xiang, Huang Junyi, et al. Effects of Sterilization and Storage Methods on Microbes and Quality of Sauced Beef [J]. Food Technology, 2020, 45 (03): 151-158. DOI:10.13684/j.cnki.spkj.2020.03.024.

[13] GB 5009.3-2016. National Food Safety Standard - Determination of Moisture in Food [S].

[14] Qingsen L, Pengcheng D, Lemonia-Christina F, et al. Preliminary investigation into the prediction of indicators of beef spoilage using Raman and Fourier transform infrared spectroscopy [J]. Meat Science, 2023, 200 109168-109168. DOI:10.1016/j.meatsci.2023.109168.

[15] Zhang Shunjun, Wang Dongliang, Chen Hongzhu, et al. Effect of ultra-high-pressure sterilization on the quality of marinated meat products during storage [J]. Meat Research, 2023, 37(12): 54-60. DOI:10.18720/j.cnki.1005-9389.2023.12.008.

[16] Lin HM, Hung YC, Deng GS, et al. Effect of partial replacement of polyphosphate with alkaline electrolyzed water (AEW) on the quality of catfish fillets [J]. Food Control, 2020, 112: 107117. DOI:10.1016/j.foodcont.2020.107117.

[17] Fu Li, Liu Yili, Gao Xueqin, et al. Changes of storage quality of sauced beef with low sodium salt [J]. Food Industry Technology, 2020, 41(07): 44-48+54. DOI:10.13386/j.issn1002-0306.2020.07.008.

[18] Ge Xiaotong, Wang Hongli, Yin Mingyu, et al. Studies on correlation of texture properties of frozen instant sea cucumber [J]. Chinese Journal of Food Science, 2023, 23(1): 326-334. DOI:10.16429/j.1009-7848.2023.01.035.

[19] Yang Shuang, Yang Ping, Xu Lin, et al. Effect of ultra-high pressure combined with low temperature storage on quality of marinated beef [J]. Food Industry Technology, 2021, 42(21): 334-343. DOI:10.13386/j.issn1002-0306.2021.21.046.

[20] Yuan Xianqun. Research on quality changes of stewed meat in seasoning [D]. Chongqing: Southwest University, 2012

[21] Li Yan, Fu Huijing, Wu Xueping, et al. Quality Changes of Braised Beef during Storage after Two Cycles of Sterilization with Different Methods [J]. Modern Food Technology, 2022, 38(12): 255-263. DOI: 10.13982/j.mfst.1673-9078.2022.12.038.

[22] Esmer OK, Irkin R, Degirmencioglu N, et al. The effects of modified atmosphere gas composition on microbiological criteria, color and oxidation values of minced beef meat [J]. Meat Science, 2011, 88(2): 221-226. DOI:10.1016/j.meatsci.2011.03.015.

[23] Zhang Ting. Study on the freshness and quality changes of beef at different storage temperatures [D]. Xi'an: Shaanxi Normal University, 2016.

[24] Zhen S, Fang-wei Y, Xia L, et al. Effects of Freezing and Thawing Treatments on Beef Protein Secondary Structure Analyzed with ATR-FTIR [J]. Guang pu xue yu guang pu fen xi = Guang pu, 2016, 36(11): 3542-6. DOI:10.3724/SP.J.1123.2016.03542.

[25] Li Dayu. Experimental Study on the Effects of Different Sterilization Processes and Packaging Techniques on the Storage Quality of Spiced Beef [D]. Changchun: Jilin University, 2020.

[26] Li Su, Zhou Huimin, Zhao Bing, et al. Analysis of Volatile Flavor Compounds in Stewed Beef with Broth during Storage [J]. Food Science, 2020, 41(18): 203-209. DOI:10.13386/j.issn1002-0306.2020.18.028.

[27] Gong H, Yang Z, Liu M, et al. Time-dependent categorization of volatile aroma compound formation in stewed Chinese spicy beef using electron nose profile coupled with thermal desorption GC–MS detection [J]. Food Science and Human Wellness, 2017, 6(03): 137-146. DOI:10.1016/j.fshw.2017.03.005.

[28] Gong Hui, Shi Zhijia, Yang Zhen, et al. Changes in Volatile Flavor Components in Soup Stock for Spiced Beef during Repeated Use [J]. Meat Research, 2017, 31(12): 41-49. DOI:10.7506/rlyj1001-8123-201712007.

[29] Li Juan. Flavor Profiling of Marinated Beef Collected from Different Regions of China [D]. Beijing: Chinese Academy of Agricultural Sciences, 2018.

[30] Pan Xiaoqian, Zhou Huimin, Li Su, et al. Changes in Odor-active Compounds during Storage and Analysis of Off-flavor Substances in Stewed Marinated Beef [J]. Food Science, 2021, 42 (22): 240-248. DOI:10.7506/spkx1002-6630-20201217-208

[31] Song Yiting, Kang Jun, Zhu Yanli, et al. Change Rule of Volatile Flavor Substances of Braised Beef During Storage Based on SPME-GC-MS [J]. Chinese Seasoning, 2024, 49(04):54-59. DOI: 10.3969/j.issn.1000-9973.2024.04.009.

[32] Song Ze, Xu Xiaodong, Xu Rui, et al. Analysis of Flavor Characteristics of Stewed Beef from Different Carcass Parts [J]. Food Science, 2019, 40(04):206-214. DOI: 10.7506/spkx1002-6630-20180104-050.