Study on Effects of Curing Process on Characteristics of Marinated Beef Products

Bo HOU[1,2], Jiamin ZHANG[2*], Wei WANG[2], Ting BAI[2], Lili JI[2]

1. College of Food and Bioengineering, Chengdu University, Chengdu 610106, China; 2. Meat Processing Key Lab of Sichuan Province, Chengdu University, Chengdu 610106, China

Abstract [**Objectives**] This study was conducted to compare the effects of different curing processes on the characteristics of marinated beef. [**Methods**] Marinated beef was obtained by two curing processes: static curing and injection and vacuum tumbling curing. The effects of the two curing processes on the production rate, curing absorption rate, water content, soluble protein content, amino acid nitrogen content, texture characteristics and microstructure of the product were compared. [**Results**] Compared with static curing, the production rate of marinated beef increased by 10%, the curing absorption rate increased by 28%, the texture and microstructure were improved, and the water content increased, while the soluble protein content decreased. As a result, the sensory score was higher. There was no significant difference in the content of amino acid nitrogen, but it decreased compared with raw meat. To sum up, injection and vacuum tumbling curing is more conducive to the processing of marinated beef. [**Conclusions**] This study provides a theoretical basis for the industrial production of marinated beef, and lays a foundation for in-depth exploration of injection and vacuum tumbling curing technique of marinated beef.

Key words Marinated beef; Curing process; Microstructure; Texture; Brine injection

DOI: 10.19759/j.cnki.2164-4993.2024.03.016

Beef is rich in protein, essential amino acids, minerals, vitamins and other nutrients, and has the characteristics of delicious meat, low fat, low cholesterol and so on. It is a high-quality meat resource[1-3] and occupies an important position in China's meat industry. From the analysis of beef production, China has jumped to the top three in the world[4]. China has a long history in the processing of beef products, forming rich product categories, such as marinated beef, beef jerky, beef floss, hand-torn beef, *etc.*, especially sauced marinated beef, which is deeply loved by the public because of its rich flavor and delicious taste. Many sauced marinated beef products with local characteristics have also been developed all over the country, such as Zhoujiakou beef in Henan, Zhangfei beef in Sichuan, spiced marinated beef in Sanzhenzhai, Zhejiang, and sauced beef in Huguo Temple in Beijing. Traditional processing of marinated beef mainly includes raw material sorting, cutting, curing, marinating, cooking and other steps, of which curing and cooking are particularly important to the quality of products.

Traditional processing of marinated beef in China is mostly workshop-style production, and the production scale and output are not large. Therefore, curing and cooking are mostly traditional manual processing, that is, directly mixing treated meat with marinade and standing for dry curing, or soaking in curing liquid for wet curing, and then cooking. The curing process takes a long time, and it is easy to cause uneven curing and bacterial growth. For large-scale production, the traditional curing process are no longer sufficient to meet production needs[5]. With the progress of traditional meat processing techniques and equipment, adopting modern processing techniques to improve the traditional process is the only way for the development of traditional meat products. Brine injection combined with vacuum tumbling curing is one of the important production and processing technique formed by the development of modern meat product industry, which has been widely used in the processing of western-style meat products. At present, some large meat processing enterprises in China have also adopted this process to process sauced marinated products, but in many small factories, traditional curing processes are still adopted[6].

Compared with traditional curing methods (such as dry curing and wet curing), the injection and tumbling curing technique not only overcomes the shortcomings of traditional curing processes, such as long curing time, low efficiency and easy microbial pollution[7], but also can improve the production rate of products, enhance the water retention of meat and improve the quality of meat products in terms of color, flavor and texture[8-13]. At present, the research on curing for improving the quality of meat products mainly focuses on factors such as tumbling methods and tumbling conditions, but there has been no report on injection and vacuum tumbling curing[14-19]. In this study, the effects of traditional static curing process and injection and vacuum tumbling curing process on the characteristics of marinated beef products were systematically compared, providing a theoretical basis and data support for the application and promotion of injection and vacuum tumbling curing technique and enterprise production and processing.

Materials and Methods

Materials and reagents

Beef ham: provided by Yibin Jiuniu Agricultural Development Co., Ltd.; condiments, spices and additives: provided by Western Wenda Food Ingredients Co., Ltd.

Received: March 28, 2024 Accepted: June 6, 2024

Bo HOU (1991 -), male, P. R. China, teaching assistant, master, devoted to research about food processing and safety.

* Corresponding author.

Formaldehyde, sodium hydroxide, phenolphthalein, ethanol, copper sulfate, potassium sodium tartrate, potassium iodide, potassium chloride, potassium phosphate, calcium chloride, ethylenediamine tetraacetic acid and hydrochloric acid were all analytically pure. Potassium hydrogen phthalate was reference substance. Crystallized bovine serum albumin was a biochemical reagent. All the reagents were purchased from Chengdu Kelong Chemical Reagent Factory.

Instruments and equipment

ZYZ-48 saline injection machine, Zhucheng Mingyang Food Machinery Co., Ltd.; BVRJ-30 vacuum tumbling machine, Jiaxing Expro Industrial Co., Ltd.; DCG-9030B electrothermal constant-temperature blast drying oven, Shanghai Senxin Test Instrument Co., Ltd.; TGL-20M high-speed tabletop freezing centrifuge, Changsha Xiangyi Centrifuge Instrument Co., Ltd.; UV1801 spectrophotometer, Beijing Ruili Analytical Instrument Co., Ltd.; TAXTPlus texture analyzer, Stable Micro System Co., Ltd., UK; PHS-3C-01PH meter, Hefei Qiaosi Instrument Equipment Co., Ltd.; BSA124S-CW electronic balance, Sartorius Scientific Instruments Co., Ltd.; inverted microscopic imaging analysis system, Shanghai precision Instruments Co., Ltd.

Experimental methods

Curing process Pretreatment of raw materials: Beef was washed and divided into pieces with uniform size of about 500 g. The processed beef was divided into two equal groups.

Group A (standing and curing group): Based on 100% of beef mass, 2.1% of salt, 1% of white sugar, 0.3% of monosodium glutamate, 0.01% of sodium nitrite, 0.1% of D-sodium ascorbate and 0.3% of compound phosphate were added, and after mixing evenly, the beef was cured at 0 – 4 ℃ for 24 h in a static state.

Group B (Injection and vacuum tumbling group): According to the proportions of salt 7%, white sugar 3%, monosodium glutamate 1%, nitrite 0.025%, D-sodium ascorbate 0.25%, compound phosphate 1% and ice water 88%, brine was prepared for injection. The brine was injected into the meat pieces with a saline injection machine, and the injection rate was determined to be 30%. The injected beef was placed in a vacuum tumbling machine and tumbled in vacuum at 0 – 4 ℃ for 2 h. The rotational speed of the tumbling machine was set to 13 r/min, and the vacuum degree to 0.08 MPa. After tumbling, the beef was allowed to stand at 0 – 4 ℃ for 8 h.

Cooking in marinade: A marinating solution was prepared according to the proportions of water 100%, salt 2.2%, monosodium glutamate 1%, soy sauce 6%, white sugar 2%, caramel 5%, and compound spice 0.4%. After the water was boiled, the cured beef was put in. After the liquid was boiled with big fire, the fire was turned down to cook the beef in a state of slightly boiling for 1 h. After cooking, the beef was fished out and cooled before testing and analysis.

Determination methods

Production rate of marinated beef According to the method from Liu *et al*.[20], the surface soup of marinated beef was drained, and the whole batch of sample was weighed while it was hot. The mass of marinated beef was m_2, and the mass of raw material was m_1. The arithmetic average of three parallel measurements was taken.

$$\text{Production rate (\%)} = m_2/m_1 \times 100$$

Curing rate According to the method from Ding *et al*.[21], the mass of the sample before curing was recorded as m_1, and after curing, the sample was dried with absorbent paper and weighed to record the mass as m_2. The sample of each group was measured in parallel for 3 times, and the average value was taken.

$$\text{Curing rate (\%)} = (m_2 - m_1)/m_1 \times 100$$

Water content Referring to the direct drying method of GB/T 5009.3-2016[22], each group was measured in parallel for 3 times, and the average value was taken.

Amino nitrogen content Referring to the acidity meter method in GB/T5009.235-2016[23], each sample was measured in parallel for 3 times and the average value was taken.

Soluble protein content Referring to the method from Liu, Li *et al*.[24–25], about 4 g of trimmed sample was put into a homogenizer, and added with 40 ml of precooled (0 – 4 ℃) extraction buffer [100 mmol KCl, 20 mmol K_3PO_4 (7 mmol K_2HPO_4, 18 mmol K_2PO_4), 1 mmol $CaCl_2$, 1 mmol EDTA, adjusted to pH of 7.0 with HCl, and stored at 0 – 4 ℃]. Homogenization was performed in an ice bath at a high speed (16 000 r/min) for 30 s. Next, the homogeneous liquid was poured into a 50 ml centrifuge tube and freeze-centrifuged for 15 min (10 000 r/min, 0 – 4 ℃) to obtain a supernatant, which was poured into a small beaker. Subsequently, the supernatant was determined for the soluble protein content by the biuret method. Each sample was measured in parallel for 3 times, and the average value was taken. The regression equation of the standard curve was as follows:

$$y = 0.042\,3x + 0.097 \qquad R^2 = 0.999\,8$$

Texture determination With reference to Lee *et al*.'s method[26], texture analysis was carried out by using a TA-XTPlus texture analyzer of Stable Microsystems Co., Ltd. With an A/Mores tool, each group of sample was tested at positions the same as the direction of muscle fibers. The testing parameters were as follows: speed before testing 2 mm/s, testing speed 1 mm/s, speed after testing 10 mm/s, cutting depth 20 mm, startup mode atuo-15 g, and data acquisition rate 500 pps. Each sample was measured in parallel for 3 times, and the average value was taken.

Microstructure observation Referring to Cao *et al*.'s method[27] with some modifications, the meat sample was cut into 0.5 cm × 1.0 cm × 0.5 cm cuboid pieces, which were soaked in 20% HNO_3 at 0 – 4 ℃ for 12 h, and its microstructure was observed under an inverted imaging system.

Sensory assessment criteria The appearance, color, texture, smell and taste of marinated beef were evaluated by 10 trained sensory evaluators, with a total score of 100 points, and the average value was taken as the sensory score after excluding abnormal values. The sensory evaluation criteria are shown in Table 1 below.

Table 1 Sensory assessment criteria

Item	Assessment criteria (full score of 100 points)	Score
Appearance (20)	The meat pieces are complete, with no obvious holes and no damage on the surface.	16 – 20
	The meat pieces are relatively complete, with a few holes and no damage on the surface.	11 – 15
	The meat pieces are damaged or some parts are missing, and there are many holes on the surface.	1 – 10
Color (20)	It has the inherent color of marinated beef, and the section is rose red uniformly.	16 – 20
	It has the inherent color of marinated beef, and the section is rose red, which is uneven at some parts.	11 – 15
	The surface color is dull, and there are many parts with incomplete or uneven color on the cut surface.	1 – 10
Texture (20)	The meat is firm, elastic, moderate in hardness and masticability, but not dry or loose.	16 – 20
	The meat is relatively compact, elastic and chewy.	11 – 15
	The meat is hard or loose, inelastic, and dry or too soft when chewing.	1 – 10
Smell (20)	The beef is rich in flavor and has no peculiar smell.	16 – 20
	The beef has a slightly light flavor and no peculiar smell.	11 – 15
	The beef has a light flavor and a peculiar smell.	1 – 10
Taste (20)	It has the inherent taste of marinated beef, rich meat flavor and no peculiar smell.	16 – 20
	It has the inherent taste of marinated beef, which is relatively good, and there is basically no peculiar smell.	11 – 15
	It tastes poor and has fishy smell or other peculiar smell.	1 – 10

Data processing

The experimental data were statistically analyzed by SPSS 21.0 for windows software. The results were expressed by Mean ± *SD*. The significant differences between the groups were obtained using one-way ANOVA, and the DUNCAN method was used for multiple comparisons. The difference was significant at $P < 0.05$ and extremely significant at $P < 0.01$.

Results and Analysis

Effects of different curing processes on production rate of marinated beef

The analysis results of the production rate of marinated beef are shown in Fig. 1. Injection and tumbling curing could significantly promote the absorption of curing solution ($P < 0.01$) and significantly improve the production rate of marinated beef ($P < 0.01$). It was because static curing can only be carried out through the slow infiltration of the surface, and the brine can't go deep into the meat. Injection and vacuum tumbling is to directly inject the brine into beef, and then in the process of vacuum tumbling, the negative pressure formed by vacuum and the mechanical action of tumbling further loosen beef fiber and make the brine more permeable and more evenly distributed and absorbed, thus significantly improving the curing absorption rate[28–30]. Meanwhile, the mechanical action of tumbling is also beneficial to the dissolution of myosin, which improves the adhesion and water retention of beef after marinating and cooking[31], thus achieving the effect of improving the production rate.

Effects of different curing processes on water content of marinated beef

As shown in Fig. 2, the water content of beef after standing and curing was significantly lower than that of raw meat ($P < 0.01$), because the internal blood in the raw beef was separated out under the action of salt in the brine. Injection and vacuum tumbling curing could also separate out blood, but the curing liquid was injected into the meat by mechanical action, which made it evenly distributed, thus ensuring that the water content did not decrease, and the difference was not significant ($P > 0.05$). After cooking in marinade, the water content decreased due to the heating treatment, and the difference was significant ($P < 0.01$). However, the injection and vacuum tumbling curing group still had a high water content, which was because the curing liquid was evenly distributed in the meat by mechanical and physical action, and the addition of compound phosphate further improved the adhesion and water retention of beef after cooking in marinade.

Effects of different curing processes on soluble protein content and amino acid nitrogen content of marinated beef

The determination results of soluble protein and amino acid nitrogen contents in marinated beef are shown in Fig. 3. Curing methods and cooking caused significant differences on soluble protein content ($P < 0.01$), and the values were lower than that of raw meat, with significant differences ($P < 0.01$), which was because of the precipitation of amino acids and protein from beef during curing. Meanwhile, due to the mechanical action of injection and vacuum tumbling curing, the surface of the meat pieces was mechanically damaged, which led to the precipitation and loss of protein, lipids and flavor substances in the muscle. The precipitation of protein reduced soluble protein content, so the soluble protein content in the injection curing group was low[20].

The effects of different curing processes on amino acid nitrogen content after cooking in marinade were not significant, but the values were higher than that of raw meat with significant differences ($P < 0.01$), which was caused by the precipitation of amino acids and protein from beef during curing. Meanwhile, due to injection and vacuum tumbling, the mechanical effects of beating and needle arrangement were produced between the meat pieces and the wall of the tumbling machine, which caused mechanical damage to the surface of the meat pieces and led to the precipitation and loss of protein, lipids and flavor substances in the muscle. The precipitation of protein and lipids reduced the content of amino nitrogen, so the content of amino nitrogen in the injection curing group was low[20]. It would have an impact on meat flavor in the later stage.

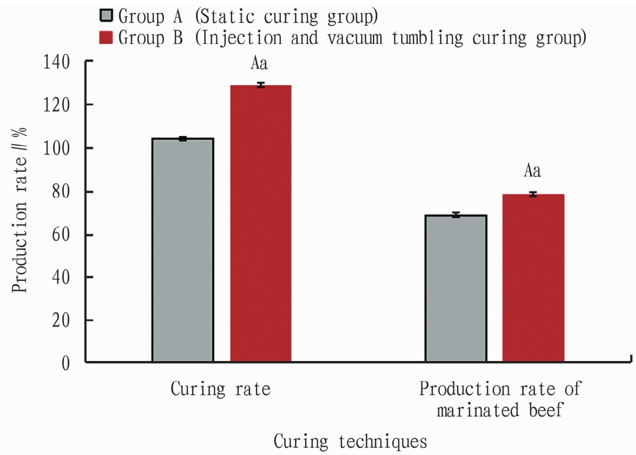


Fig. 1 Effects of different curing techniques on curing rate and production rate of marinated beef

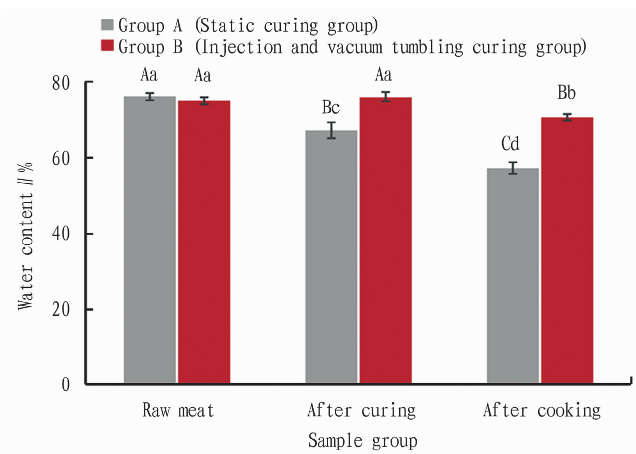


Fig. 2 Effects of different curing techniques on water content of marinated beef

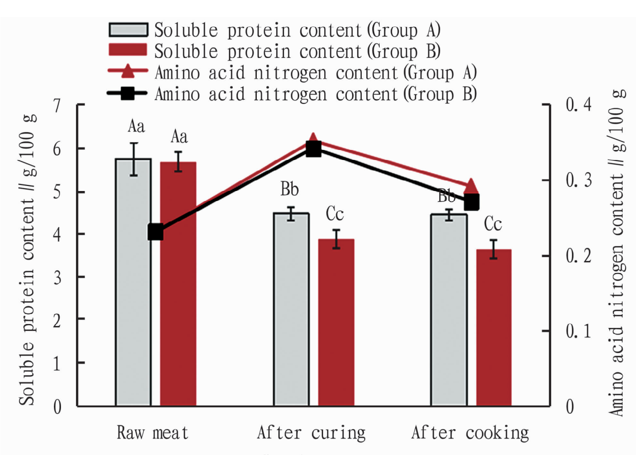


Fig. 3 Effects of different curing processes on soluble protein content and amino acid nitrogen content and in marinated beef

Meanwhile, soluble protein content is positively correlated with amino acid nitrogen content and meat tenderness[32]. Both standing curing and injection and vacuum tumbling curing denatured the protein of beef, but injection and vacuum tumbling curing had a greater impact.

Effects of different curing techniques on texture of marinated beef

The determination results of the structural characteristics of marinated beef by different curing processes are shown in Fig. 4. Compared with the raw meat, the hardness and masticability of the beef undergone static curing increased, which was because that the ambient temperature of standing and curing was 0 – 4 ℃, and the low temperature led to the rigidity of beef surface, which changed the intercellular binding force[33], and the precipitation of blood after curing also affected its texture characteristics. Due to the strong physical action of injection needle and mechanical tumbling, the original structure of beef was destroyed, and the hardness and masticability of beef decreased significantly compared with the static curing group and the raw beef ($P < 0.01$). Injection and vacuum tumbling curing made the meat pieces loose, and the curing solution entered, making part of the protein dissolve out and evenly distribute on the surface of the meat pieces. And after marinating and cooking, the protein denatured to form gel, which made the meat pieces adhere and connect with each other, improving the texture of the product[34]. There was no significant difference in texture when comparing the texture after cooking in marinade with that after curing, which showed that the effect of curing on texture was far greater than that of cooking in marinade.

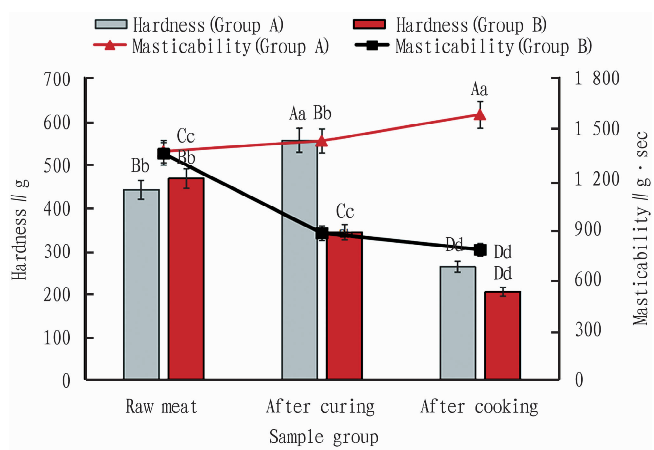
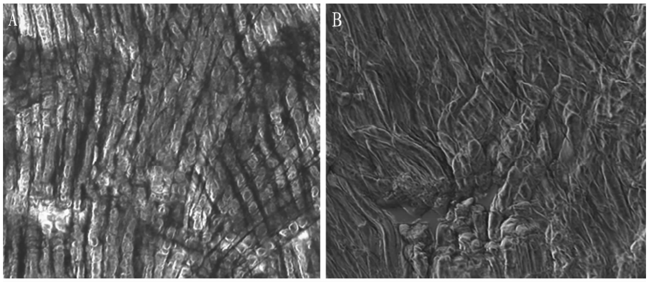


Fig. 4 Effect of different curing techniques on hardness and masticability of marinated beef

Effects of different curing techniques on microstructure of marinated beef

Under microscopic observation, the microstructure of marinated beef is shown in Fig. 5. Fig. 1(A) shows the microstructure of static curing, and the muscle tissue is arranged regularly, tightly and without damage, without holes, and the gap area between muscle fibers is very small. Fig. 1(B) shows the microstructure of injection and vacuum tumbling curing, in which the muscle tissue is loosely arranged with obvious holes, and the gap area between muscle fibers is large and interrupted, indicating that the injection and vacuum tumbling curing can seriously destroy the original tissue structure of beef and improve its texture characteristics.



A. Static curing; B. Injection and vacuum tumbling curing.

Fig. 5 Microstructure of marinated beef under different curing process conditions

Sensory score results of marinated beef

The results of sensory evaluation showed that the appearance of marinated beef in the static standing group was good, but because static curing couldn't penetrate the beef evenly, its internal and external colors were uneven, and its texture and flavor were weaker than that of marinated beef in the injection and vacuum tumbling curing group. The injection and vacuum tumbling curing group used an injection gun and vacuum tumbling curing had a strong mechanical effect, so that the curing liquid could penetrate into the beef evenly, making it uniform in color, good in taste and texture, and rich in flavor, but meanwhile, the existence of the injection gun left obvious pinholes on its surface, which made its appearance poor. The overall sensory score for marinated beef in the injection and vacuum tumbling curing group was 72 points, which was higher than 53 points in group A.

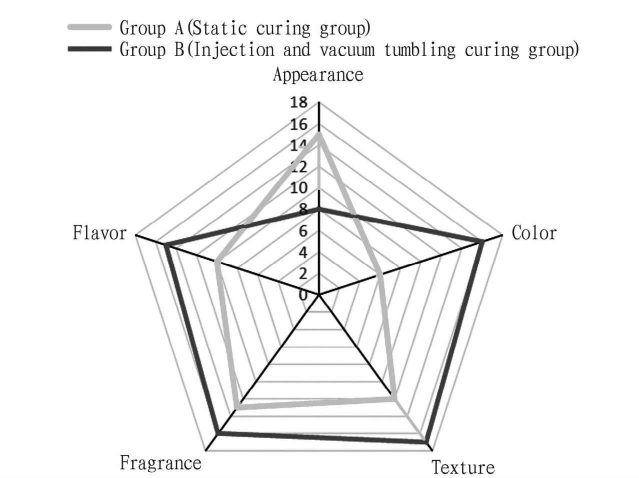


Fig. 6 Sensory scoring results

Conclusions and Discussion

With beef as the raw material, it was processed by two ways: static curing and injection and vacuum tumbling curing. The experimental results showed that compared with static curing, the production rate of marinated beef increased by 10%, the curing absorption rate increased by 28%, and the texture and microstructure were improved, while the hardness and masticability were reduced. The microstructure observation showed that the difference was obvious. The water content increased, while the soluble protein content decreased. As a result, the comprehensive sensory score was higher. However, there was no significant effect in amino acid nitrogen content. To sum up, injection and vacuum tumbling curing was more beneficial to the processing of marinated beef, but it also damaged the structure of beef greatly, leaving obvious pinholes. The reason was that in order to achieve better production, the injection ratio parameter of the saline injection machine was adjusted to 30%, and the optimal technique of saline injection ratio needs to be further studied. This study provides a theoretical basis for the industrial production of marinated beef and lays a foundation for the exploration of the injection and vacuum tumbling curing technique of marinated beef.

References

[1] XIE XL, LI X, ZHANG CH, *et al.* Effects of different drying methods on physical characteristics of beef jerky[J]. Transactions of the Chinese Society of Agricultural Engineering, 2015(S1): 346–354, 380. (in Chinese).
[2] JIA J. Study on tissue structure and bionics of high-quality beef[D]. Changchun: Jilin University, 2006. (in Chinese).
[3] LIU L, ZHOU GH, WANG LZ, *et al.* Effects of conditioning time of beef quality[J]. Food Science, 2002(1): 33–36. (in Chinese).
[4] SUN YF. Difficulties and countermeasures of beef supply in China[J]. The Chinese Livestock and Poultry Breeding, 2017(3): 16–17. (in Chinese).
[5] WANG W, JI LL, ZHANG JM, *et al.* Research on development technology of beef processing industry in Sichuan Province[J]. Journal of Chengdu University: Natural Science, 2016(4): 338–341. (in Chinese).
[6] XIA JJ, LI HJ, HE ZF, *et al.* Effects of different curing strategies on quality characteristics of beef[J]. Journal of Southwest University: Natural Science, 2016(2): 12–19. (in Chinese).
[7] CHANG HJ. Study on the change of intramuscular collagen characteristics of beef under different processing conditions and its influence on quality [D]. Nanjing: Nanjing Agricultural University, 2010. (in Chinese).
[8] LACHOWICZ K, SOBCZAK M, GAJOWIECKI L. Effects of massaging time on texture, rheological properties, and structureof three pork ham muscles[J]. Meat Science, 2003, 63(2): 225–233.
[9] XU WM, YIN YT, ZHU YZ, *et al.* Effect of different curing strategies on curing rate and quality index of duck meat[J]. Modern Food Science & Technology, 2014(8): 201–205. (in Chinese).
[10] KATSARAS K, BUDRAS KD. The relationship of the micro-structure of cooked ham to its properties and quality[J]. Lebensmittel Wissen Schaft Und Technologie, 1993, 26(3): 229–234.
[11] TYSZKIEWICZ I, JAKUBIEC-PUKA A. Ultrastructure of mechanically tenderised pork muscle[J]. Meat science, 1995, 41(3): 273–282.
[12] XIAO SONG, DAREN CORNFORTH, DICK WHITTIER, *et al.* Nitrite spray treatment to promote red color stability of vacuum packaged beef [J]. Meat Science, 2015(99) 8–17.
[13] XU BC, SUN JQ, HAN YX, *et al.* Effect of mechanical pretreatment technology for raw meat on qualities of porcine sliced ham[J]. Transactions of the Chinese Society of Agricultural Engineering, 2012, 28(14): 250–255. (in Chinese).
[14] YU LH, SUN JX, LI P, *et al.* Effects of ultrasound-aided pressure swing tumbling on the eating quality of duck[J]. Meat Research, 2016 (12): 17–21. (in Chinese).
[15] ZHONG BJ. Effect of knead-salting parameters on the quality of quick-frozen stewed meat[J]. Meat Industry, 2016(11): 1–4. (in Chinese).
[16] WANG J, YAN WJ, WU HZ, *et al.* Effect of modern tumbling on quality characteristics of a salt substitute dry-cured ham [J]. Science and Technology of Food Industry, 2016(9): 228–234. (in Chinese).

(Continued on page 74)

[10] LIU LY. Analysis on the growth effects of Chinese fir mixed with *Phoebe zhennan* and *Liquidambar formosana*[J]. Forestry Prospect and Design, 2021, 41(2): 47–49, 52. (in Chinese).
[11] CHEN ZH. A Study on the growth effect of mixed forest of *Taiwania Flousiana* and *Schima superba*[J]. Journal of Green Science and Technology, 2021, 23(5): 97–100. (in Chinese).
[12] XU GR. Effects of different afforestation ways on the growth of *Cunninghamia lanceolata* and *Castanopsis hystrix*[J]. The Journal of Hebei Forestry Science and Technology, 2020(1): 18–20. (in Chinese).
[13] HE GY. The early effect of different slope positions in mixed forestation of Chinese fir-*Alniphyllum fortunei*[J]. Forestry Prospect and Design, 2018, 38(3): 28–30. (in Chinese).
[14] ZHU RW. Effects of slope position and slope direction on growth of mixed forest of fir and *Liquidambr formosana* Hance[J]. Modern Agricultural Science and Technology, 2020, (4): 122–123, 125. (in Chinese).
[15] ZHU YL, LOU ZH, XIAO XY, *et al.* Investigation and analysis of the current development situation of *Cunninghamia lanceolata*: Take Jing'an County in Jiangxi Province as an example[J]. South China Forestry Science, 2021, 49(2): 20–25. (in Chinese).
[16] MIAO FT, LIU BQ. Study on sustainable management of state-owned forest farms in subtropical regions[J]. Issues of Forestry Economics 2018(6): 27–33, 102. (in Chinese).
[17] TONG R, ZHOU BZ, JIANG LN, *et al.* Problems and development strategy for sustainable management of Chinese fir plantation: Based on the investigation of its national distribution[J]. World Forestry Research, 2019(2): 90–96. (in Chinese).
[18] CAO GQ, FEI YC, LU J, *et al.* The differences of soil enzyme activity and quality evaluation of *Cunninghamia lanceolata* large-diameter industrial plantation under different understory vegetation management measures[J]. Forest Research, 2020(3): 76–84. (in Chinese).
[19] CHEN WJ. Study on the growth and woodland characteristics of the second generation plantation of *Cunninghamia lanceolata* in the hilly area of central Hunan[C]. Central South University of Forestry and Technology, 2013. (in Chinese).
[20] LIN KM, YU XT, HONG W, *et al.* Effects of undergrowth plant on soil fertility in Chinese fir plantation[J]. Scientia Silvae Sinicae, 2001 (S1): 94–98. (in Chinese).
[21] CAO XY. Effects of thinning on stand growth of *Cunninghamia lanceolata* plantation[J]. Tropical Forestry, 2021(4): 26–28. (in Chinese).
[22] CAO ZH, ZHANG WB, WU ZN, *et al.* Effects of shrub cutting and thinning on the growth of *Cunninghamia lanceolata* plantations[J]. Anhui Forestry Science and Technology, 2017, 43(6): 9–13. (in Chinese).

Editor: Yingzhi GUANG Proofreader: Xinxiu ZHU

(Continued from page 68)

[17] DEUMIER F. Decontamination of deboned chicken legs by vacuum-tumbling in lactic acid solution[J]. International journal of food science & technology, 2006, 41(1): 23–32.
[18] XU WM, YIN YT, ZHU YZ, *et al.* Effect of different curing strategies on curing rate and quality index of duck meat[J]. Modern Food Science & Technology, 2014(8): 201–205. (in Chinese).
[19] JIANG YJ, GONG HK. Effects of different tumbling marination crafts on quality of thigh meat of wild duck[J]. Journal of Harbin University of Commerce: Natural Sciences Edition, 2016(4): 465–468. (in Chinese).
[20] LIU QY, BAI WD, HUANG M, *et al.* Effect of vacuum tumbling conditions on the quality and yield of marinated beef[J]. Food and Fermentation Industries, 2013(2): 205–212. (in Chinese).
[21] DING YT, HU H, LYU F, *et al.* Effect of tumbling curing method on curing quality of duck meat[J]. Food and Fermentation Industries, 2013(2): 00–204. (in Chinese).
[22] Standardization Administration of the People's Republic of China, Ministry of Health of the People's Republic of China. GB/T5009.3-2016 Determination of moisture in foods[S]. Beijing: China Standards Press, 2016. (in Chinese).
[23] Standardization Administration of the People's Republic of China, Ministry of Health of the People's Republic of China. GB/T5009.235-2016 Determination of amino acid nitrogen in foods[S]. Beijing: China Standards Press, 2016. (in Chinese).
[24] LIU HH, ZHANG JH, WANG YL, *et al.* Effect of papain tenderized on proteolysis and tenderness of air-dry chicken muscle made by spent layers[J]. Science and Technology of Food Industry, 2009(1): 174–177. (in Chinese).
[25] LI LH. Study on the effect of ultrasonic treatment on tenderization of mutton[D]. Baoding: Hebei Agricultural University, 2003. (in Chinese).
[26] LEE YS, SAHA A, XIONG R, *et al.* Changes in broiler breast fillet tenderness, water–holding capacity, and color attributes during long-term frozen storage[J]. Journal of Food Science, 2008, 73(4): E162–E168.
[27] CAO J, SUN W, ZHOU G, *et al.* Morphological and biochemical assessment of apoptosis in different skeletal muscles of bulls during conditioning[J]. Journal of animal science, 2010, 88(10): 3439–3444.
[28] SHIOWSHUH SHEEN, JENNIFER CASSIDY, BUTCH SCULLEN, *et al.* Inactivation of a diverse set of shiga toxin-producing *Escherichia coli* in ground beef by high pressure processing[J]. Food Microbiology, 2015: 52.
[29] WANG YT, LI YX. Effect of saune injection on curing of the traditional Goubangzi smoked chicken[J]. Food Research and Development, 2009(6): 56–58. (in Chinese).
[30] JIA N, LI BW, KONG BH. Effect of the brine injection and edible gums on the quality of marinated beef [J]. Food and Fermentation Industries, 2015(3): 96–99. (in Chinese).
[31] MAHA HAJMEER, ERDOGAN CEYLAN, JAMES L MARSDEN, *et al.* Impact of sodium chloride on *Escherichia coli* O157: H7 and *Staphylococcus aureus* analyzed using transmission electron microscopy[J]. Food Microbiology, 2005, 23(5).
[32] WANG XJ, WANG XX, LIN J, *et al.* Changes in functional properties of myofibrillar proteins during postmortem aging of dazu black goat meat[J]. Food Science, 2015, 36(21): 79–84. (in Chinese).
[33] SUN TL, ZHANG XM, ZHANG P, *et al.* Effect of controlled freezing point storage combined with vacuum packaging on texture and histological structure of beef[J]. Food Science, 2013, 34(22): 327–331. (in Chinese).
[34] ZHAO GM, YIN F, ZHU CZ, *et al.* Effect of tumbling on the quality of beef brined ham[J/OL]. Food Science: 1–12 [2020–01–19]. http://kns.cnki.net/kcms/detail/11.2206.TS.20191025.1330.006.html. (in Chinese).

Editor: Yingzhi GUANG Proofreader: Xinxiu ZHU