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Effect of Different Sterilization Methods on the Quality of Antarctic Krill (*Euphausia superba*) Sauce

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Abstract: The Antarctic krill (*Euphausia superba*) sauce was used as the experimental object to evaluate the effects of various sterilizing methods on the quality and safety of Antarctic krill sauce by measuring sensory, texture, rheology, color and taste. The findings revealed that Antarctic krill sauce has a distinct flavor, a rich texture, and a high acceptance. As a result of these findings, the odor and sensory ratings are bad. When compared to other treatment groups, the ultraviolet (UV) treated group had worse taste and smell scores (p<0.05) than the control group (CG). Meanwhile, the UV had the greatest L^* value (28.97) in color, as well as hardness and hardness work values of 166.90 g and 9.33 mJ, suggesting that the hardness values and hardness work values of Antarctic krill sauce, on the other hand, displayed low tissue structural uniformity. The hardness and hardness work values of Antarctic krill sauce with microwave (MV) treatment, on the other hand, were 128.80 g and 6.59 mJ, respectively, while the rheological value was 17.49 Pa·s. The rheological value showed that Antarctic krill sauce treated with MV had low shear force and acceptable texture uniformity. Importantly, the MV treatment had little effect on the flavor, odor, and color of Antarctic krill sauce. In general, supply fundamental facts and innovative ideas for high-value commercial technology, quality enhancement, and comprehensive Antarctic krill usage. The study's findings will be presented in the following publications in the future.

Keywords: Antarctic Krill Sauce, Sterilization Methods, Quality Changes, Rheological

1. Introduction

Antarctic krill (*Euphausia superba*) is abundant in protein and vital amino acids, as well as minerals, unsaturated fatty acids, and active compounds (such as autolysis enzymes and astaxanthin) [1-3]. With limited global fisheries resources, Antarctic krill has emerged as an important marine biological resource, and the development and use of Antarctic krill has emerged as a vital trend for the sustainable growth of Chinese fisheries [4-6]. Existing Antarctic krill goods, however, are still confined to shrimp oil and shrimp meal, and there have been few reports of high-value-added products that successfully use the unique flavor and freshness of Antarctic krill [7, 8]. As a result, the creation of Antarctic krill sauces using Antarctic krill as the major flavor component, emphasizing its unique taste and freshness, may significantly contribute to the successful increase of its added value and industrial growth.

Antarctic krill are particularly active in the autolytic enzyme system, and heating loosens the tissue and allows proteins to be readily broken down [9]. This exposes Antarctic krill to microbial infestation during processing, transit, and storage, lowering economic value and food safety. To assure the quality and safety of the product, fish processing enterprises primarily use high temperature, microwave, UV, and pasteurization. Traditional high-temperature sterilization may successfully reduce the quantity of germs while also extending the product's shelf life. High-temperature sterilization, on the other hand, can readily damage heat-sensitive substances, resulting in nutritional and taste component loss in the food [10]. Microwave sterilizing use microwaves' thermal/non-thermal impact to inactivate bacteria for a short period of time while having little influence on volatile substances in food [11, 12]. In the microwave sterilization procedure, uneven heating of food might be a concern owing to uneven materials and forms [13]. UVC sterilization may successfully reduce the quantity of germs in the product while maintaining as much fresh flavor and nutrients as possible [14-16]. Finally, while pasteurization can prevent flavor and nutrient loss, it cannot have the intended fatal impact on some microbes, and the product's quality might occasionally suffer as a result [17]. Therefore, the quality and safety of Antarctic krill sauce is significantly influenced by the selection of the best sterilizing procedure.

By utilizing the distinct flavor and texture of Antarctic krill, Antarctic giant krill was employed in this study as the primary raw material to make the Antarctic krill sauce. Additionally, the samples were sterilized using four widely used commercial sterilization techniques: microwave (MV), low temperature long time (LTLT), high temperature short time (HTST), and ultraviolet (UV) processing. The samples were tested for texture, rheology, color difference, taste, and texture, as well as sensory analysis and microbial residues, to determine changes in quality, safety, and the benefits and drawbacks of various commercial sterilization methods for Antarctic krill sauce. The objective is to offer fundamental information for process optimization, quality enhancement, and thorough exploitation of high-value Antarctic krill commodities.

2. Materials and Methods

2.1. Materials and Agents

Antarctic krill was donated by the 36th Antarctic expedition. Jinhua ham was obtained from Zhejiang Palma Food Co., Ltd., edible oil, garlic, chili, dried red pepper, rock sugar, oyster sauce, soy sauce, and salt were all available for purchase in supermarket in Shanghai.

Lysine decarboxylase test medium, rabbit blood agar plate, Baird-Parker agar plate, nutritional agar, salmonella spp. chromogenic medium, triose iron agar, bright green lactose bile salt broth, and laureth sulfate tryptone broth purchased from Beijing Solabao; Brain Heart Infusion (BHI) USA BD, agar powder Beijing Solabao, alkaline peptone water, sodium chloride, egg yolk saline, and potassium tellurite were obtained from Sinopharm (Shanghai) Chemical Reagent Co..

2.2. Preparation of Antarctic Krill Sauce

The thawing procedure was used to treat 500 g of undamaged Antarctic krill without any black heads [18]. Antarctic krill that had been thawed was cooked in boiling water, then the cooked krill was drained and dried at 80°C until the moisture content was no greater than 30%. The sterilized bags containing the dried Antarctic krill were kept at 4°C overnight to achieve moisture equilibrium. While other Antarctic krill smaller than 3 cm in size were combined with crushed shrimp in a ratio of 3:5 (*g/g*), the 3-5 cm Antarctic krill were chosen from the overnight equilibrium of Antarctic krill and crushed in a cooking machine.

The garlic, chili pepper, and dried chili pepper were crushed in a cooking machine as raw materials, and the Jinhua ham was steamed for 15 minutes before being chilled and shredded. Cooking oil (400 mL) is heated, the crushed raw ingredients are added separately, stirred constantly for 5 minutes, then the Antarctic krill combination and Jinhua ham are added, stirred continuously for 10 minutes, the seasoning is added, stirred continuously for 5 minutes, and the pan is then removed from the heat. The Antarctic krill sauce was then put into 50 mL sterile glass jars when the temperature was lowered to room temperature.

2.3. Sterilization of Antarctic Krill Sauce

The precise treatment procedures are listed in Table 1 and included pasteurization (LTLT), high temperature sterilization (HTST), microwave sterilization (MV), and ultraviolet sterilization (UV) of the produced Antarctic krill sauce. The control group (CG) (untreated group) and the treated Antarctic krill paste were chilled to room temperature and then stored at 4°C.

Table 1. *Sterilization treatments for Antarctic krill sauce.*

Sterilization methods	Processing conditions
MV	850 W, 130 s
LTLT	90°C, 60 min
HTST	121°C, 15 min
UV	40 W, 15 min

2.4. Determination of Color

The sample L^*, a^*, and b^* values were measured by using CM-700d colorimeter (Konica, Japan). The color difference ΔE *is* calculated in equation (1).

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

Note: In the formula ΔL^*, Δa^*, Δb^* the difference between the standard reference white plate and the measured sample chromaticity parameters L^*, a^*, b^* values.

2.5. Determination of Qualitative and Structural Properties

Select compression mode, place the TA2/1000 (Brookfield RST Rheometer, Shanghai Ametek Industrial Technology Co. Ltd.) probe above the center of the Antarctic krill sauce bottle mouth, pre-test rate of 2 mm/s, measurement rate of 1 mm/s when the probe touches the Antarctic krill sauce to start the test, trigger force of 5 g, probe gradually vertical deep into the Antarctic krill sauce system, test distance of 15 mm after the probe began to rise, post-test rate of 1 mm/s. The probe has completed the test by leaving the Antarctic krill sauce system. In which the probe falling load was used as a qualitative indication, and the probe rising load was used as a viscosity indicator.

2.6. Determination of Rheological Properties

The VT-40-20 rotor (Brookfield RST Rheometer, Shanghai Ametek Industrial Technology Co. Ltd.) was inserted deep into the Antarctic krill sauce with a rotor entry depth of 3 cm, and the pressure (Pa) on the rotor was measured at a shear rate of 5 s^{-1} and a test temperature of 25°C for 60 s. The rheological properties of the Antarctic krill sauce were expressed as η and calculated in equation (2).

$$\eta = \frac{\tau}{\dot{\gamma}} \quad (2)$$

Note: The formula τ is the shear force (unit expressed in pa), $\dot{Y}$ is the shear rate (unit expressed in 1/s).

2.7. Sensory Evaluation

Ten students and instructors with typical sensory sensitivity and culinary professional backgrounds evaluated the Antarctic krill sauce. The participants were instructed on how to assess the samples using the evaluation criteria in Table 2, and 5 g samples were collected for each test.

Table 2. *Criteria for sensory evaluation of Antarctic krill sauce.*

Indicators	Standard			
Color (10%)	Lusterless. Dull color (0~40)	Poor luster. Not red bright enough (40~60)	The sauce is more oily and moist. But the color is not red and bright enough (60~80)	Overall oiliness of the sauce and the color is more red and bright (80~100)
Scent (20%)	Almost no shrimp flavor. Burnt smell (0~40)	Heavy or insufficient sauce flavor. The overall smell is not coordinated (40~60)	Aroma unique to shrimp and abalone, with a slightly lighter smell (60~80)	Outstanding seafood flavor, overall odor coordination, no odor (80~100)
Taste (40%)	discomfort in the mouth. Too spicy and too salty. With a bitter taste (0~40)	salty and spicy heavy or light. The fresh taste is lighter and A little bitter aftertaste (40~60)	The right amount of saltiness. Better mouthfeel. Lighter fresh taste (60~80)	Fresh and spicy and delicious. The right amount of saltiness. Fine texture and Outstanding freshness and flavor (80~100)
Texture (30%)	The organization is very heterogeneous and Oil separation phenomenon occurs Poor chewiness (0~40)	Uneven organization. Too thin or too thick Average chewiness (40~60)	The tissue is more uniform and Slightly thin or slightly thick Better chewiness (60~80)	Uniform organization. with the right consistency. Good chewiness (80~100)

2.8. Data Analysis

Raw data were processed in Microsoft Excel 2016, reported as mean standard deviation, and assessed for significance of differences ($p<0.05$) in IBM SPSS Statistics 24 program using Duncan multiple comparisons, then plotted in Origin 2018.

3. Results and Discussion

3.1. Color Analysis

Table 3 displays the color analysis findings of Antarctic krill sauce with various sterilizing methods. There was no significant difference in a^* values across all treatment groups ($p>0.05$), indicating that the various therapies had minimal influence on a^* value change. The CG group's L^* and b^* values were 27.35 and -12.86, respectively, and the HTST treatment group's L^* and b^* values were significantly lower than those of the CG group (23.24 and -15.05, respectively) ($p<0.05$), indicating that the brightness of Antarctic krill sause diminished and the color gradually became darker after HTST treatment. The phenomena of Antarctic krill sauce color shift may be related to oxidation of Antarctic krill sauce due to its denser tissue structure and reduced water content after high temperature treatment of the samples during the maturation process, which causes it to darken [19-21]. Furthermore, the high temperature treatment stimulated the merad reaction, which resulted in browning of the product, which may have contributed to the darkening of the Antarctic krill sauce [22, 23]. The L^* and b^* values of the samples were lowered to some extent by the LTLT and MV groups, but there was no significant difference in color difference between the two groups ($p>0.05$). This suggests that UV light has a positive influence on the brightness of Antarctic krill sauce. This finding is comparable to that of Shen's results [24].

Table 3. *Color analysis of Antarctic krill sauce with different sterilization methods.*

Processing group	L^*	a^*	b^*	ΔE
CG	27.35 ± 0.81^{a}	2.24 ± 0.42^{a}	-12.86 ± 0.35^{ab}	72.56 ± 0.78^{a}
MV	27.26 ± 0.28^{a}	2.16 ± 0.00^{a}	-12.90 ± 0.78^{ab}	72.64 ± 0.24^{a}
UV	28.97 ± 0.50^{a}	2.06 ± 0.19^{a}	-11.18 ± 1.09^{a}	70.23 ± 1.16^{a}
LTLT	26.47 ± 0.13^{ab}	2.04 ± 0.13^{a}	-13.13 ± 0.16^{ab}	73.32 ± 0.22^{ab}
HTST	23.24 ± 2.74^{b}	2.34 ± 0.32^{a}	-15.05 ± 1.54^{b}	76.90 ± 2.99^{b}

3.2. Textural Characterization

The Antarctic krill paste texture data exhibited an increasing trend, with varied variations depending on the sample handling. The UV group had the highest hard force and hard work values of 166.90 g and 9.33 mJ, respectively, which were significantly higher than the other samples (p<0.05) (Table 4), which could be attributed to UV treatment denaturing actin and myosin and a more dense tissue structure. The LTLT group's hard force and work done were 125.50 g and 6.74 mJ, respectively, which were considerably lower than those of the CG group (p<0.05). This means that the samples' shear force and hardness indices dropped, the tissue structure of the meat became more loose, and the tenderness rose. Cross et al. [25] proposed that when the heating temperature exceeded 70°C, the collagen fibers began to denature after heat, destroying the muscle's integrity, the structure of the myogenic fibers became loose, the muscle structure was damaged, and shear force values began to decrease [26, 27]. The hard force work value of HTST was 7.65 mJ, which was somewhat higher than that of CG, indicating that the product's textural features were connected not only to the sterilization temperature but also to the sterilization duration. The hard force work values of the MV group were 128.80 g and 6.59 mJ, respectively, and were substantially lower than those of the CG-treated group (p<0.05).

Table 4. *Texture characteristics of Antarctic krill sauce with different sterilization methods.*

Processing group	Hard force (g)	Work done by hard force (mJ)	Adhesion force (g)	Adhesion (mJ)
CG	156.85±0.64^{a}	7.57±0.03^{a}	0.00	0.01
MV	128.80±0.57^{b}	6.59±0.08^{b}	0.00	0.03
UV	166.90±2.19^{c}	9.33±0.08^{c}	0.00	0.03
LTLT	125.50±4.03^{b}	6.74±0.16^{b}	0.00	0.02
HTST	146.70±0.57^{d}	7.65±0.11^{a}	0.00	0.05

It is worth noting that the adhesion of all Antarctic krill sauces was 0 g, and it was similarly low. This suggests that Antarctic krill sauce lacked the stickiness and gelatinous condition found in regular fermented sauces. On the contrary, the Antarctic krill sauce has enough texture to highlight their distinct aromas.

3.3. Rheological Characteristics Analysis

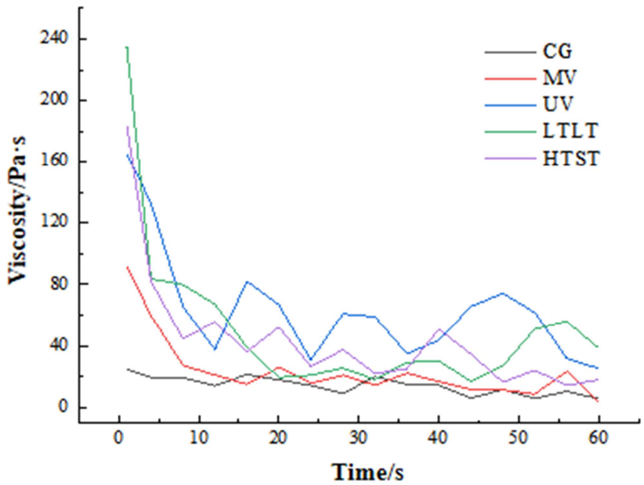

Figure 1. *Rheological properties of Antarctic krill sauces with different sterilization methods.*

The sauce's suitable homogeneity and texture can enhance the flavor, improve the consumer's perception time, and increase the release of the presenting substances [28]. Figure 1 depicts the rheological properties of Antarctic krill sauce with various sterilizing procedures. All samples' rheological values did not enter the stable phase of the test until 10 s. As a result, the rheological values after 10 seconds were chosen to examine the homogeneity and texture of the samples. The UV group's rheological characteristic curves became wavy data values, with the greatest value being 55.64 Pa·s and the minimum value being 16.44 Pa·s. This shifting scenario with a big gap demonstrated that the UV group samples were not homogeneous in texture, which was compatible with the UV group's textural structure. The HTST and LTLT groups had lower rheological values than the UV group, with mean values of 35.67 Pa·s and 29.33 Pa·s, respectively. In this experiment, the rheological curves of the MV group were flatter and less volatile. This shows that the MV group's samples are more homogeneous and less impacted by granularity.

3.4. Sensory Analysis

The sensory findings of the Antarctic krill cause revealed that the CG had higher color and odor sensory scores, with an overall acceptance of 82.83, indicating that the created Antarctic krill paste had greater sensory quality (Figure 2). When compared to CG, MV, UV, LTLT, and HTST all had lower ratings in each sensory index, demonstrating that the four sterilizing treatments impacted the sensory indices to varying degrees. The sensory ratings for color and odor of HTST were 42 and 48, respectively, considerably lower than the other samples (p<0.05), demonstrating that high temperature sterilization degraded the control group's color and odor. UV was not significantly different from CG in taste (p>0.05) and significantly higher than the other, indicating that UV caused less damage to Antarctic krill sauce taste substances (p<0.05), while overall acceptability reached 74.23, the highest compared to the other sterilization methods. However, the sensory score for the texture of the Antarctic krill sauce in the UV-treated group was only 61.5, which differed significantly from the CG, indicating that UV had an effect on the homogeneity of the samples in terms of tissue structure, which was consistent with the textural and rheological analyses. In terms of color and odor, LTLT and MV were not substantially different from the CG ($p<0.05$). The total acceptance was 73.18 and 71.68, indicating a very minor effect on the items. In terms of overall sensory acceptability, CG had a better overall sensory acceptability than the other sterilization techniques, UV had the least influence on the sensory ratings of the samples when compared to the other sterilization methods, and HTST had a substantially ($p<0.05$) lower overall sensory acceptability than the other samples.

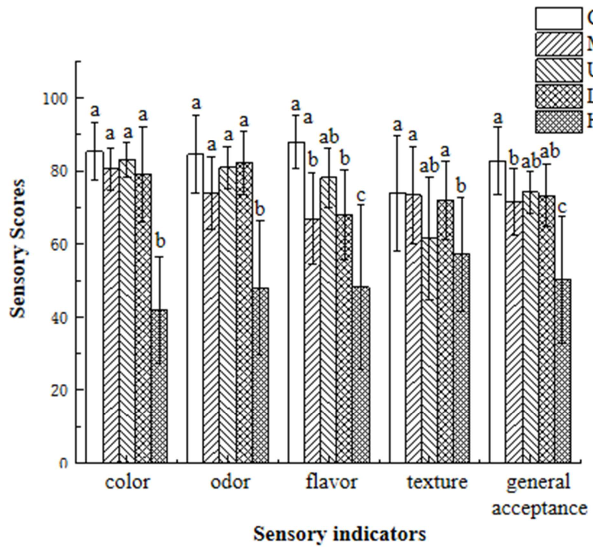

Figure 2. *Sensory evaluation of Antarctic krill sauce with different sterilization methods.*

4. Conclusion

In this study we analyzed the effects of different sterilization methods on the quality of Antarctic krill sauce. When compared to the other sterilization methods, UV had the highest overall acceptability, with higher color L^* values, and the hard force and hard force work values obtained for the texture were 166.90 g and 9.33 mJ, respectively, which were significantly ($p<0.05$) greater than the other samples, and the rheological value was 55.57 Pa.s, which was significantly ($p<0.05$) greater than the other samples, but the UV The texture and rheology characteristic curves fluctuated a lot, and the difference between the greatest and minimum rheological values was 39.20 Pa·s. The tissue structure's uniformity was compromised. HTST degraded the product's taste and flavor compounds owing to the influence of temperature, and the sensory score was considerably ($p<0.05$) lower than the other treatment groups, as were the HTST color L^* and b^* values. Lower hard force and hard force work values, lower rheological values, and improved texture homogeneity were found in the MV and LTLT. According to the results of the study and comparison, sensory acceptability was favorably connected with the L^* and b^* values and negatively correlated with the volatility of the texture rheological characteristics curve. In General, the results in our study provided a new method for Antarctic krill usage.

References

[1] Chi H., Li XX, Yang XS. Processing status and utilization strategies of Antarctic krill (*Euphausia superba*) in China [J]. World Journal of Fish and Marine Sciences, 2013, 5 (3): 275-281.

[2] Chi H, Li XY, Yang XS. Progress in processing and utilization of Antarctic krill [J]. Natural Products Research and Development, 2010, 22 (8): 283-287.

[3] Chi H, Li XY, Yang XS, et al. Effect of red wine extract on the antioxidant effect of Antarctic krill during storage [J]. Journal of Agricultural Machinery, 2013, 44 (2): 153-159.

[4] Chen XZ, Xu ZL, Huang HL. Current status of Antarctic krill resource utilization and analysis of development strategies in China [J]. China Fisheries Science, 2009, 16 (3): 451-458.

[5] Chi H, Li XY, Yang XS, et al. Quality changes of Antarctic krill under freezing temperature and its shelf life analysis [J]. Journal of Aquaculture, 2012, 36 (1): 153-160.

[6] Hu LP, Zhang XM, Zhang HW, et al. Changes in amino acid and trypsin degradation products of Antarctic krill before and after autolysis [J]. Food Science, 2019, 40 (11): 9-14.

[7] Liu Q, Liu ZD, Lu Y, et al. Research and development trend of Antarctic krill products [J]. Fisheries Information and Strategy, 2014, 29 (2): 115-121.

[8] Wang Y, WANG R, Chang Y, et al. Preparation and thermo-reversible gelling properties of protein isolate from defatted Antarctic krill (*Euphausia superba*) byproducts [J]. Food Chemistry, 2015, 188 (1): 170-176.

[9] Yang X, Shi YF, Cai YQ, et al. Quality Changes and Safety Evaluation of Ready-to-Eat Roasted Antarctic Krill (*Euphausia superba*) During Storage at Room Temperature (25°C) [J]. Journal of Ocean University of China, 2023, 22 (1): 235-241.

[10] Li BS. Heat sterilization and non-heat sterilization characteristics and methods [J]. Grain and Oil Processing and Food Machinery, 2001 (7): 14-15.

[11] Wu GP, Li CY, Gu FL, et al. Effect of different fungicidal methods on the flavor quality of black pepper [J]. Journal of Tropical Crops, 2021, 42 (2): 527-534.

[12] Li X, Zhang XC, Ou XQ, et al. Study on the effect of microwave sterilization on volatile flavor compounds in the skin fat and muscle of Rongchang marinated goose [J]. Food Research and Development, 2020, 41 (1): 42-50.

[13] Shen HL, Song P, Yang YL, et al. Research progress of microwave sterilization technology in food industry [J]. Food Industry Science and Technology, 2012, 33 (13): 361-365.

[14] Yan Y, Li HS, Ren ZF. Research status of ultraviolet sterilization technology [J]. Petrochemical Technology, 2011, 18 (4): 60-63.

[15] Kim T, Silva JL, Chen TC. Effects of UV irradiation on selected pathogens in peptone water and on stainless steel and chicken meat [J]. Journal of food protection, 2002, 65 (7): 1142-1145.

[16] Schenk M, Loredo AG, Raffellini S, et al. The effect of UV-C in combination with H_2O_2 treatments on microbial response and quality parameters of fresh cut pear discs [J]. International Journal of Food Science and Technology, 2012, 47 (9): 1842-1851.

[17] Feng L, Rui HM. Effect of different sterilization methods on the quality of salt-baked chicken wing roots [J]. Food and Fermentation Industry, 2006 (11): 111-115.

[18] Chi H, Li XY, Yang XS, et al. Effects of thawing methods and conditions on the quality of Antarctic krill [J]. Food and Machinery, 2011, 27 (1): 94-97.

[19] Xue CY, Zhang Q, Liang P. Effect of temperature on the quality of anchovy fillets during cold air drying [J]. Food Research and Development, 2016, 37 (23): 29-33.

[20] Qiao M, Fletcher DL, Smith DP, et al. The effect of broiler breast meat color on pH, moisture, water-holding capacity, and emulsification capacity [J]. Poultry Science, 2001, 80 (5): 676.

[21] Kong FB, Olivera A, Tang JM, et al. Salt effect on heat-induced physical and chemical changes of salmon fillet (O. gorbuscha) [J]. Food Chemistry, 2008, 106 (3): 957-966.

[22] Requena DD, HALE A, GREEN DP, et al. Detection of discoloration in thermally processed blue crab meat [J]. Journal of the Science of Food and Agriculture, 1999, 79 (5): 786-791.

[23] Li DY, Yuan Z, Liu ZQ, et al. Effect of oxidation and maillard reaction on color deterioration of ready-to-eat shrimps during storage [J]. LWT-Food Science and Technology, 2020, 131: 109696.

[24] Shen AQ, Chen SS, Feng ZS, et al. Effect of preservatives synergistic UV sterilization on the sterilization effect and quality of oil tatsoi [J]. Modern Food Science and Technology, 2020, 36 (1): 136-142.

[25] Cross HR, Carpenter ZL, Smith GC. Effects of intra- muscular collagen and elastin upon bovine muscle tenderness [J]. Journal of Food Science, 2010, 38 (6): 998-1003.

[26] Zang DC, Zhou GH, Xu XL, et al. Changes of duck meat tenderness and ultrastructure during heating [J]. Journal of Jiangsu Agriculture, 2007, 23 (5): 475-480.

[27] Wattanachant S, Benjakul S, Ledward DA. Effect of heat treatment on changes in texture, structure and properties of Thai indigenous chicken muscle [J]. Food Chemistry, 2005, 93 (2): 337-348.

[28] Dai XX, Li BS. A review of the rheology of food thickeners [J]. China Food Additives, 2007 (4): 138-142.