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Optimization of the Technology of Marinated Beef Tendon Jelly with Curdlan Gel

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Abstract: A new kind of tendon jelly was developed with cow tendon as raw material and adding curdlan gel. On the basis of three single factor tests, including the amount of curdlan gel, the amount of salt and the braising time, the optimal processing technology of tendon jelly was determined by response surface optimization and verification tests with sensory score and hardness as evaluation criteria. The results showed that the optimum process formula of tendon jelly was the curdlan gel addition of 0.7%, the stewing time of 4.14 hours, and the salt addition of 0.38%.

Keywords: Beef tendon jelly; Curdlan gel; Processing technology.

1. Introduction

Marinated tendon jelly is a traditional food, which uses beef tendon as the raw material. Beef tendon itself is rich in collagen, proteoglycan, calcium and other nutrients, and it adds a unique taste after gels into jelly state [1]. The collagen in beef tendon is very helpful for maintaining the stability and elasticity of the joint, which can relieve joint pain and discomfort, strengthen the muscles and bones, and improve the pain and weakness of the waist and knee. At the same time, collagen is also an important component of skin, bone, cartilage and other tissues, which can promote metabolism, enhance skin elasticity and luster, and delay aging.

Curdlan gel (Cur), also known as thermal gel and condensed polysaccharide, is a water-insoluble glucan produced by microorganisms and composed of β-1, 3-glucoside bonds. It is water suspension can form two kinds of gels with different structures at low and high temperatures, which are called low freezing heat reversible gel (TRC) and high freezing heat irreversible gel (TIRC) [2]. It is unique gel properties can improve the edible quality of food [3], such as improving the taste, texture and water retention of food [4], and it has a wide range of applications in food [5], medicine [6], biology[7] and other fields, and can be used as a thickening agent, stabilizer and gelling agent. At present, curdlan gel, as a new green food additive, has been widely used in food processing industries such as frozen food, bionic food, meat products and aquatic products due to its good gel-property, water retention, thermal stability and frost resistance[8], with an annual demand of more than 10,000 tons.

With the improvement of people's requirements for nutrition, functionality, health care and other aspects of food, low-fat foods with beauty effects are gradually welcomed by consumers[9]. Jellies are not only high in collagen but also low in fat and calories. At present, the tendons on the market are mostly produced by manual workshops, and the ability to form gel is poor and the melting point is low, which makes it limited in industrial production[10]. On the one hand, the addition of curdlan gel can improve the gel characteristics of marinated tendon jelly, make it more smooth and elastic, and increase the taste enjoyment of food. On the other hand, it helps the stability of marinated tendon jelly in the cold storage process, reduce the possibility of water separation and texture change, and reduce the production cost of enterprises. It is of practical value and market prospect to optimize the processing technology of marinated tendon jelly.

2. Materials and Methods

2.1. Experimental materials

beef tendon, curdlan gel (CY-2 Shandong Cuiyuan Yi kang Biotechnology Co., LTD.), distilled water, salt, spice pack, soy sauce.

2.2. Main instruments and equipment

Table 1. Major instruments and equipment

Instrument	Brand and model
Texture analyzer	TA-XT Plus
Centrifuge	CENTRIFUGR MODEL 800
Cooking Boiler	Supor EZ28BS04
Induction Cooker	Joyoung C21S-C572
Refeigerator	Haier BCD-471WDCD

2.3. Methods

2.3.1. Production of marinated spice packets

Refer to Peng Mengmeng's formula and take 100% water added as the benchmark [11]. Add 2.0% of cumin, 2.0% of star anise, 0.3% of cinnamon, 0.3% of pepper, 1.0% of orange peel, 1.0% of cayenne pepper and 2.0% of ginger as spice packs.

2.3.2. Production process of marinated tendon jelly[12]

Wash the beef tendon, blanch for 5min After blanching, remove, scrape the fat on the tendon, wash and weigh. Change the water into the pot (tendon: water is 1:4). Put the spice into the spice bag, put it into the water and boil the beef tendon together, start the stew (cold water into the pot, electromagnetic oven 1200w, when the water temperature reaches 99 degrees, adjust to 300w, start the time, and pull out the surface suspended matter and oil droplets), remove the

surface grease and foam after the stew is finished. Let cool at room temperature for 1h, refrigerate at 4 ℃ for 24h, and then form jelly.

2.4. Determination of production technology of marinated tendon jelly

2.4.1. Single factor determination of marinated tendon jelly

Three variables, namely, the amount of curdlan gel added, the stewing time and the amount of salt added, were selected to conduct a single factor experiment. 10 evaluators with sensory evaluation ability were selected to score the marinated tendon jelly according to the sensory scoring criteria in Table 2-1.

2.4.1.1 Stewing time

When stewing, take 50g of stewed frozen tendon soup at 2.5h, 3h, 3.5h, 4h and 4.5h respectively, leave to cool at room temperature for 1h, and refrigerate at 4 degrees for 24h before freezing. Sensory evaluation was carried out to select the best stewing time for follow-up experiments.

2.4.1.2 Added amount of curdlan gel

After the stewing is over, weigh 5 servings of the stewed jelly soup, 50g each. Add 0.1%, 0.3%, 0.5%, 0.7%, 0.9% curdlan gel to it respectively. Sensory evaluation was carried out to select the best dosage of curdlan gel for subsequent test.

2.4.1.3 Salt addition amount

After the stewing is over, weigh 5 servings of the stewed jelly soup, 50g each. Add 0.1%, 0.3%, 0.5%, 0.7%, 0.9% salt to them respectively. Sensory evaluation was carried out to select the best amount of salt for follow-up test.

2.4.2. Sensory evaluation method of marinated tendon jelly

Taking sensory scores as the criteria for determining the best marinated beef tendon technology, 10 sensory assessors were randomly selected from different populations to objectively evaluate three aspects of marinated beef tendon jelly: smell, taste and state, as shown in Table 2-1. [13]

Table 2-1. Sensory evaluation scoring criteria

Project	Evaluation criteria	Score
smell	No obvious odor	20-30
	Slight odor	10-20
	Strong odor	1-10
taste	Medium texture,no adhesion	20-30
	The texture is hard,with a slight sense of adhesion	10-20
	Soft texture,a sense of adhesion	1-10
state	Complete freezing,goodresilience,no juice separation phenomenon,smooth surface	30-40
	Better frozen,smooth surface,slight impurities	20-30
	No frozen,the whole into a gel,juice separation phenomenon,there is impurity	1-20

2.4.3. Optimization of production process of marinated tendon jelly

Response surface method was used to optimize the production process of marinated tendon freeze. The influencing factors were curdlan gel (X1), braising time (X2) and salt addition amount (X3), and the response values were hardness (Y1) and sensory score (Y2). Box-Behnken in Design-Expert 13 was used to Design the response surface experiment. The levels of factors are shown in Table 2-2.

Table 2-2. Response surface analysis, test factor coding and level table

Factor	Encoded values		
	-1	0	1
A curdlan gel addition amount /%	0.3	0.5	0.7
B stewing time/h	3.5	4	4.5
C salt addition amount/%	0.3	0.5	0.7

2.5. Texture determination

After the beef tendon is cooled, it is placed on a texture tester for testing. All samples are measured in parallel three times and the average value is taken. Referring to Wang Juanjuan's method [12] with slight modifications, the measurement conditions are as follows: TPA mode, P36R model probe, with a descent speed of 2.0mm/s before measurement, a measurement speed of 1.0mm/s, a rise speed of 1.0mm/s after measurement, a compression ratio of 30%, automatic trigger type, trigger force of 5g, and a residence time of 5s in secondary compression.

3. Results and Analysis

3.1. Results of single factor test

3.1.1. Added amount of Curdlan gel

Take five parts of tendon soup and add 0.1%, 0.3%, 0.5%, 0.7%, 0.9% of curdlan gel, respectively. Let sit at room temperature for 1h and freeze in the refrigerator. The effect of different amount of curdlan gel on the gelatinization of marinated tendon jelly was investigated.

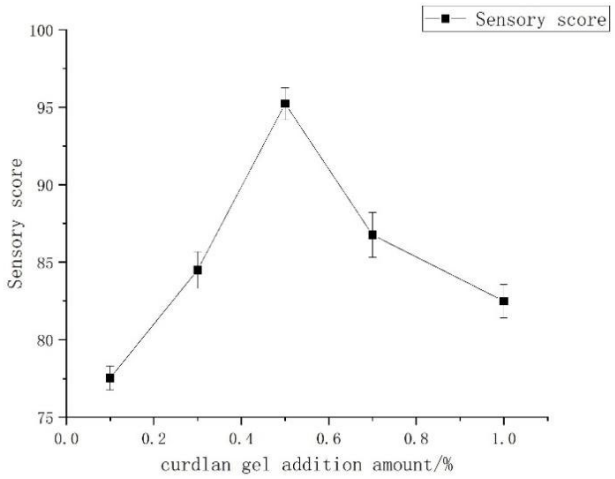

Figure 1. Effect of curdlan gel addition amount on sensory evaluation

Sensory score increases first and then decreases with the amount of curdlan gel added, as shown in Figure 1. When the content of curdlan gum was 0.1% and 0.3%, there was no significant effect on the gel of tendon jelly. And the jelly made from beef tendons is poor, with a bad taste. When the content of the curdlan gel is 0.5%, the gel property of the tendon jelly is good, the texture is moderate, and the taste is good. When the addition amount of curdlan gel is 0.7% and 0.9%, the curdlan gel has a greater impact on tendon jelly. The gel property of tendon jelly is good, but the texture is hard, which has a certain impact on the taste. These results indicate that the optimal additive amount of curdlan gel is 0.5%.

3.1.2. Stewing time

At the time points of 2.5h, 3h, 3.5h, 4h and 4.5h, 5 portions of tendon soup were taken out respectively, and left to stand at room temperature for 1h, then put into the refrigerator to freeze. The effect of different stewing time on the gelatinization of marinated tendon jelly was investigated by sensory evaluation.

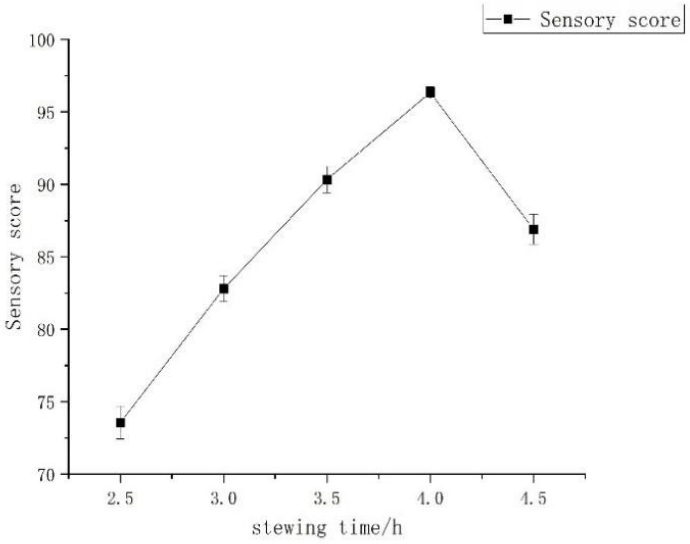

Figure 2. Effect of stewing time on sensory evaluation

When the stewing time was 4h, the sensory scores of the stewed tendon jelly reached the peak value. Subsequently, sensory scores for stewing time dropped, as shown in Figure 2. When the stewing time is 2.5h and 3h, the effect of gel of tendon jelly is poor, similar to water, with bad taste, and it becomes liquid when chewed in the mouth. When the stewing time is 3.5h, 4h, 4.5h, the beef tendon jelly is good, but when the stewing time is 3.5h, the beef tendon jelly is easy to damage when touched. When the stewing time of tendon jelly is 4 hours, the effect is similar to 4.5 hours. In order to save energy, the stewing time is selected as 4 hours.

3.1.3. Salt addition amount

Take five parts of tendon soup and add 0.1%, 0.3%, 0.5%, 0.7%, 0.9% salt, respectively. Let sit at room temperature for 1h and freeze in the refrigerator. The effect of different amount of salt on the gelatinization of marinated tendon jelly was investigated.

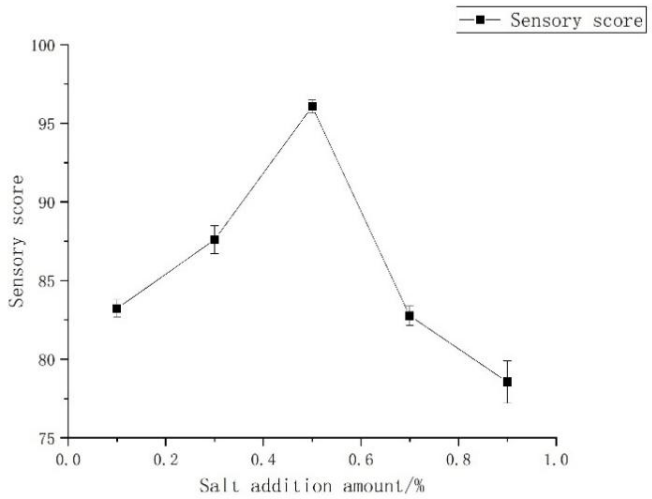

Figure 3. Effect of salt addition amount on sensory evaluation

Sensory score increases first and then decreases with the amount of curdlan gel added, as shown in Figure 3. The amount of salt added has almost no effect on the gelation effect of beef tendon jelly, mainly on the taste. When the addition amount is 0.1%, the salty taste is too weak and the sensory evaluation is low. When the addition amount is 0.7% and 0.9%, the salty taste is too strong and the sensory score is lower. When the amount of salt added is 0.3% and 0.5%, the taste is suitable, with 0.5% being the best. These results indicate that the optimal amount of salt is 0.5%.

3.2. Response surface factors

Response surface method was used to optimize the production process of stewed tendon jelly. The influencing factors include curdlan gel addition amount (A), stewing time (B) and salt addition amount (C), and the response values were sensory evaluation score (Y1) and gel strength (Y2). Box-Behnken in Design-Expert13 was used for response surface test Design, and the factor levels are shown in Table 2-2.

3.3. Response surface design test results of marinated tendon jelly

Based on the single factor test results, Design-Expert 13 software was used to carry out tests on three factors, including the addition amount of curdlan gel, the stew time and the salt addition amount, and the Box-Behnken Design combination was adopted to optimize the gelation process of marinated tendon jelly with hardness and sensory scores as the response values. The experimental design scheme and data results are shown in Table 3-1.

Table 3-1. Box-Behnken trial design and results

Standard serial number	Experiment serial number	A Curdlan gel addition amount/%	B braising times/h	C Salt addition amount/%	Hardness	Sensory score
1	17	0.3	3.5	0.5	102.23	75.88
2	6	0.7	3.5	0.5	303.891	74.66
3	1	0.3	4.5	0.5	526.788	85.33
4	10	0.7	4.5	0.5	456.787	81.77
5	9	0.3	4	0.3	451.571	95.66
6	7	0.7	4	0.3	597.681	91.67
7	16	0.3	4	0.7	320.646	94.45
8	8	0.7	4	0.7	468.121	94.78
9	11	0.5	3.5	0.3	145.135	70.22
10	4	0.5	3.5	0.3	453.364	85.55
11	14	0.5	3.5	0.7	265.914	74.55
12	5	0.5	4.5	0.7	368.426	88.33
13	12	0.5	4	0.5	437.235	91.78
14	3	0.5	4	0.5	498.775	92.89
15	13	0.5	4	0.5	535.176	94
16	15	0.5	4	0.5	453.06	95.67
17	2	0.5	4	0.5	554.491	96.44

According to the test data in Table 3-1, the multiple regression equation was fitted, and the fitting formulas for the addition amount of curdlan gel (A), the stew time (B) and the salt addition amount (C) with hardness were as follows: Y1=495.75+53.16A+

123.52B-28.08C-67.92AB+0.3412AC-51.43BC+1.49A2-149.81B2-37.73C2.

According to the test data in Table 3-2, the multiple regression equation was fitted, and the fitting formulas for the addition amount of curdlan gel (A), the stew time (B) and the

salt addition amount (C) with sensory score were as follows: Y2=94.16-1.29A+5.21B+1.89C-0.5850AB+0.5550AC-1.39BC-0.3968A2-14.35B2+0.8558C2.

Table 3-2. Response surface test results and analysis of variance

Source of variance	Sum of squares	degree of freedom	mean square	F-number	P-value	Distinctiveness
model	2.836E+05	9	2.836E+05	7.88	0.0063	**
A	22604.16	1	22604.16	5.65	0.0490	*
B	1.221E+05	1	1.221E+05	30.53	0.0009	**
C	6308.12	1	6308.12	1.58	0.2494	
AB	18450.06	1	18450.06	4.61	0.0688	
AC	0.4658	1	0.4658	0.0001	0.9917	
BC	10579.87	1	10579.87	2.65	0.1478	
A^2	9.30	1	9.30	0.0023	0.9629	
B^2	94495.98	1	94495.98	23.63	0.0018	**
C^2	5993.41	1	5993.41	1.50	0.2604	
Residuals	27988.26	7	3998.32			
Out-of-the-way items	17727.75	3	5909.25	2.30	0.2187	
Pure error	10260.51	4	2565.13			
sum	3.116E+05	16				
R^2=0.9102	R^2Adj=0.7947	R^2Pred=0.0383				
Adeq precision	9.0227					

Note: "*" indicates significant impact (P<0.05) and "**" indicates extremely significant impact (P<0.01).

As can be seen from Table 3-2, in the case of model F=7.88, p<0.001 indicates that the model is highly significant. When the coefficient of determination R^2=0.9102 and the coefficient of correction R^2Adj=0.7947, it indicates that there is a good agreement between the measured value and the predicted value of hardness, indicating that the obtained regression equation can correctly analyze and predict hardness. In this model, both primary term B and secondary term B^2 reach A very significant level, and primary term A also shows a significant level. The results showed that the stewing time and the amount of curdlan gel had significant influence on the hardness of marinated tendon jelly. The larger the F value is, the greater the influence of the test factors on the response index. The F values of the three factors are 5.65, 30.53 and 1.58 respectively, indicating that the influence degree of the three factors on the hardness is B > A > C. Among them, the stewing time has the greatest influence on the hardness of the marinated tendon jelly, followed by the amount of curdlan gel added, and the least influence is the amount of salt added. The second term B^2 hardness had a very significant effect (P<0.01).

Table 3-3. Response surface test results and analysis of variance

Source of variance	Sum of squares	degree of freedom	mean square	F-number	P-value	Distinctiveness
model	1141.81	9	1141.81	24.30	<0.0001	**
A	13.36	1	13.36	3.09	0.1224	
B	217.05	1	217.05	50.12	0.0002	**
C	28.54	1	28.54	6.59	0.0372	*
AB	1.37	1	1.37	0.3161	0.5915	
AC	1.23	1	1.23	0.2845	0.6103	
BC	7.70	1	7.70	1.78	0.2241	
A2	0.6628	1	0.6628	0.1530	0.7073	
B2	866.95	1	866.95	200.19	<0.0001	**
C2	3.08	1	3.08	0.7120	0.4267	
Residuals	30.31	7	4.33			
Out-of-the-way items	15.53	3	5.18	1.40	0.3650	
Pure error	14.78	4	3.70			
sum	1172.13	16				
R2=0.9741	R2Adj=0.9409	R2Pred=0.7683				
Adeq precision	15.7035					

Note: "*" indicates significant impact (P<0.05) and "**" indicates extremely significant impact (P<0.01).

As can be seen from Table 3-3, when model F=24.30, p < 0.001 indicates that the model is highly significant. When the missing fitting term F=15.53, p=0.3650 > 0.05, it means that the model is not significant. When the coefficient of determination R^2=0.9741 and the coefficient of correction R^2Adj=0.9409, it indicates that there is a good agreement between the measured value and the predicted value of the sensory score, indicating that the regression equation obtained

can correctly analyze and predict the sensory score. In this model, both primary item B and secondary item B^2 reached a very significant level, and primary item C also showed a significant level, indicating that the stewing time and salt addition amount in the experiment had a significant impact on the sensory scores of the marinated tendon jelly. The larger the F value, the greater the influence of the experimental factors on the response index, and the F values of the three factors were 3.09, 50.12 and 6.59 respectively, indicating that the influence degree of the three factors on the sensory score was B > C > A, among which the stewing time had the greatest impact on the sensory score of the marinated tendon jelly, followed by the amount of salt added, and the least influence was the amount of curdlan gel added.

3.4. Analysis and optimization of response surface diagram of marinated tendon jelly

In order to study the effects of various interaction conditions on the hardness and sensory scores of the marinated tendon jelly, the regression equations were calculated using Design-Expert13 software. Figures 4 and 5 show a three-dimensional response surface and contour plot of the interaction conditions to better illustrate the impact of individual variables on the response values. The Design-Expert 13 program was used to optimize the regression equation to determine the optimal dosage of three factors to achieve the optimal freezing process: 0.7% curdlan gel addition, 4.14h stewing time and 0.38% salt addition. Under this process condition, the hardness and sensory score of the marinated tendon jelly were predicted to be 565.981 and 91.7489, respectively.

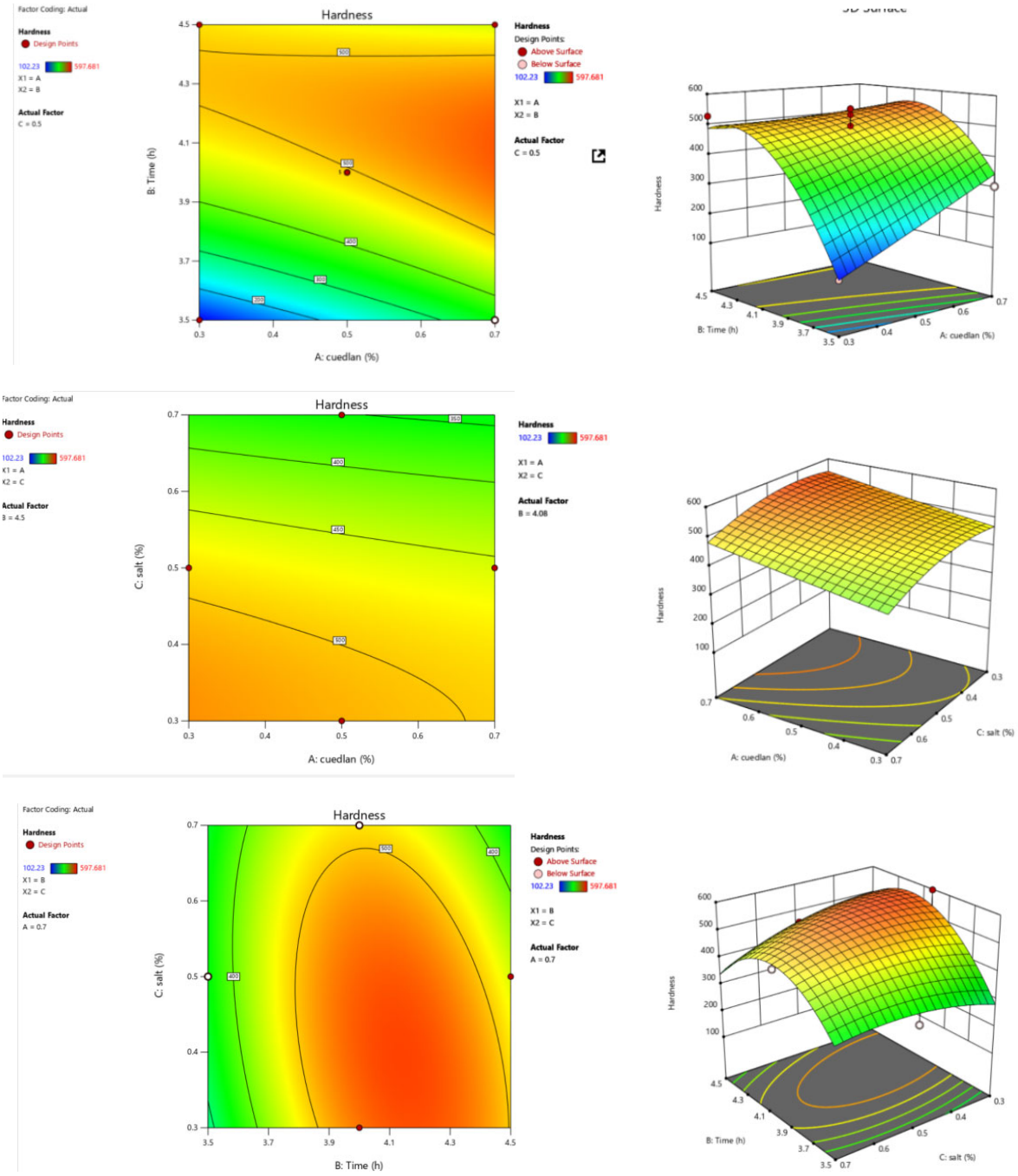

Figure 4. Response surface and contour map of the interaction of various factors in hardness

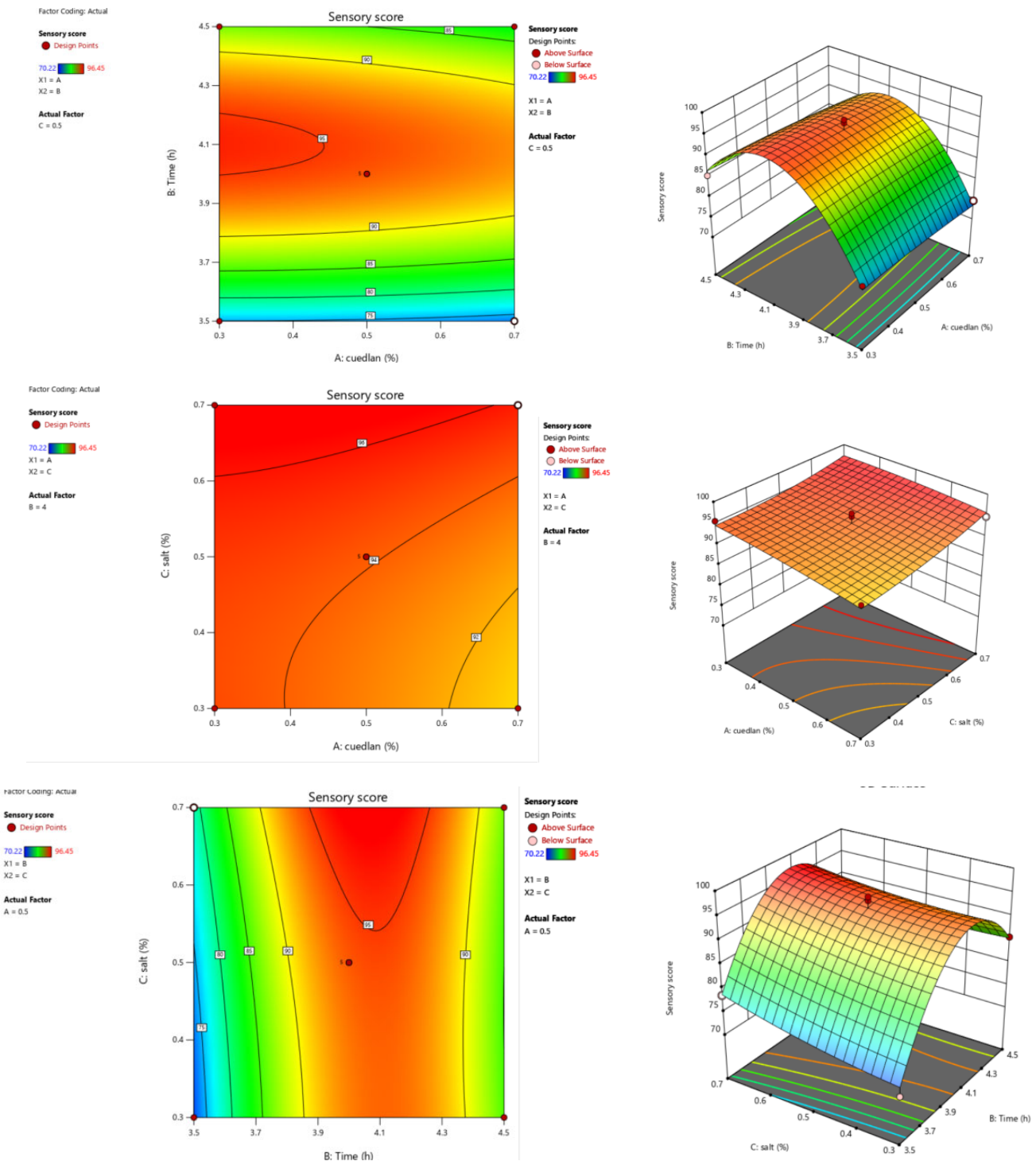

Figure 5. Response surface and contour map of the interaction of various factors in Sensory score

3.5. Verification test

Based on the mathematical model constructed by the response surface software, the parameters were optimized and analyzed, and the optimal addition amount of marinated tendon jelly was obtained as follows: Under these conditions, the hardness and sensory score of marinated tendon jelly were predicted by means of texture analyzer, which were 565.981 and 91.7489, respectively. In order to test the reliability of this method, the above optimization conditions are verified. After three sets of parallel experiments, the average hardness of the product samples obtained was 635.393, and the average sensory score was 90.5843. This shows the accuracy and reliability of this model, and also shows the feasibility of this model in practical application.

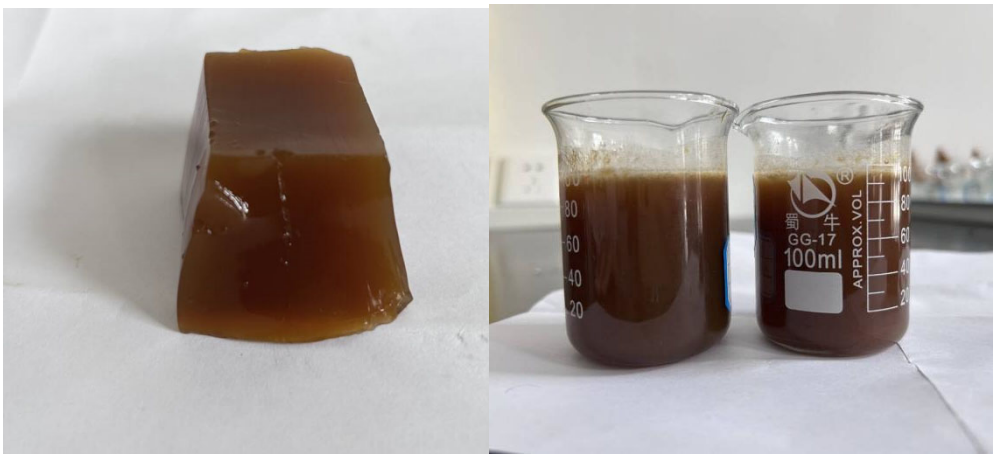

Figure 6. Photo of marinated tendon jelly

4. Conclusion

This experiment uses beef tendon as raw material to make marinated tendon jelly. The optimal conditions were obtained through single factor experiments. Using 50g tendon soup as the benchmark, the amount of curdlan gel added was 0.5%, the stewing time was 4 hours, and the amount of salt added was 0.5%. Subsequently, response surface analysis was used to design experiments, with sensory scores and hardness as response values. The optimal process conditions were obtained as follows: the amount of curdlan gel added was 0.7%, the stewing time was 4.14 hours, and the amount of salt added was 0.38%. The feasibility of the model was verified, providing a reference for the development of beef tendon.

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