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Influence of the addition of Curdlan gel on the textural properties of beef emulsified sausage

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ABSTRACT

The aim of this study was to investigate the application of Curdlan gel in beef emulsified sausage, to optimise its process parameters and to improve its textural properties in order to provide a safer and healthier way of processing meat products. Cure time, chopping time and steaming time were selected as the influencing factors to find out the optimal process combination by orthogonal test. Subsequently, the effects of different additive amounts of CY-1 and CY-2 Curdlan gel on the texture of beef emulsified sausage were investigated, and a comprehensive texture evaluation model was established. Through orthogonal tests, the optimal process combination was found to be 60 min for cure time, 20 s for chopping time, and 40 min for steaming time, and it was found that the additive amounts of CY-1 Curdlan gel of 1.5%~2.25% and CY-2 Curdlan gel of 0.75%~1.5% could improve the texture of beef emulsified sausage significantly, and produce the beef emulsified sausage with good texture characteristics. The production of beef emulsified sausage with good textural characteristics provides a certain reference for the optimization and improvement of the processing technology of beef emulsified sausage.

KEYWORDS

Beef emulsified sausage; Curdlan gel; Process optimization; Textural properties.

1. INTRODUCTION

With the improvement of living standards, consumer demand for food has shifted from pure taste to the pursuit of food nutrition, health, safety and other aspects, the improvement and innovation of traditional meat products has become a hotspot for food industry research [1, 2]. Improvement and innovation of traditional meat products have become a hot research topic in the food industry. Beef emulsified sausage, as a kind of meat product loved by consumers, its quality and taste directly determine the consumers' willingness to buy. However, the traditional beef emulsified sausage has some problems in terms of textural stability, taste and water retention, which need to be improved by the use of additives and process optimisation, which may pose potential risks to human health. Therefore, the search for natural and healthy alternatives has become an important research direction in the food industry.

Curdlan gel is a water-insoluble dextran produced by microorganisms with β-1,3-glycosidic bonds, and its aqueous suspension can form two structurally different gels at low and high temperatures, namely, low-solidifying thermo-reversible gel and high-solidifying thermo-irreversible gel [3]. Curdlan gel, due to its good gelation, water-holding, thermal stability, and antifreeze properties, as a new type of green food additives has been widely used in food processing industry [4]. When Curdlan

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gel is used as a thickener in meat food, we can make use of its gel properties and add it to ham sausage, bacon sausage, meat products in sauce and marinade, etc. Adequate addition of Curdlan gel can make a qualitative leap in the product's taste, appearance and storage time, which can greatly improve the sales volume and reduce the production cost as much as possible [5].

Texture, as a core physical property of meat products, has a decisive influence on their eating quality, flavour, stability and appearance. Textural parameters such as hardness and elasticity are key indicators for evaluating the quality of meat products. Some studies have shown that the special structure of Curdlan gel can form a stable network structure in food, which can replace some chemical additives, and the addition of Curdlan gel in appropriate amounts can effectively improve the textural properties of meat products [6]. Zhao Bing et al [7] showed that the hardness, elasticity and other textural parameters of lamb ham increased with the addition of Curdlan gel. On the other hand, Jiang Shuai et al [8] found that the addition of 0.3% Curdlan gel to sausages significantly improved the textural stability and overall acceptability of sausages with high moisture content. In addition, the application of Curdlan gel in low-salt and low-fat meat products has also achieved remarkable results. Zhao Chunbo et al [9] showed that the textural properties of emulsified sausage could be effectively enhanced by adding 0.3% of Curdlan gel at the same time when NaCl was partially replaced by KCl.JIANG et al [10] found that the textural and gel properties of frankfurter sausage could be significantly improved by the moderate addition of Curdlan gel. Therefore, through the scientific and rational addition of Curdlan gel and other gelling agents, the textural properties of meat products can be effectively improved, and then improve their overall quality, which provides a powerful technical support for the sustainable development of meat products industry.

The aim of this study was to investigate the application of Curdlan gel in beef emulsified sausage, to optimise the production process of beef emulsified sausage processing, and to improve the textural properties by adding Curdlan gel in order to provide a safer and healthier way of processing meat products. Firstly, the optimal process combination was identified through sensory evaluation and orthogonal test. The optimum amount of Curdlan gel (CY-1) and Curdlan gel (CY-2) added to beef emulsified sausage and their effects on the textural properties of emulsified sausage are not yet available. Subsequently, we analyse and study the effects of different additives of CY-1 and CY-2 Curdlan gel on the texture of beef emulsified sausage, investigate the differences in the effects of different types of Curdlan gel on the texture of beef emulsified sausage and the optimal additives in beef emulsified sausage processing, and construct a comprehensive evaluation model of texture and structure to assist in the optimization and improvement of the beef emulsified sausage processing process, so that it can provide certain reference for the production of beef emulsified sausage in the enterprise. It can provide a certain reference for the production of beef emulsified sausage, promote the wide application of Curdlan gel in the food industry, and promote the healthy development of the food industry.

2. MATERIALS AND METHODS

2.1. Materials And Reagents

The raw materials used in this experiment were fresh beef tendon and brisket; salt, Shandong Feicheng Refined Salt Factory Co. Ltd; sugar, Angie's yeast Co. Ltd; black pepper powder and five-spice powder, Shanghai Aroma Foods Co. Ltd; monosodium glutamate (MSG), Lotus Health Industry Group Co. Ltd; and bovine intestinal coating, Yixuan Halal Beef Intestinal Co.

Table 1. Main reagents

Reagent name	Specification/Model	manufacturer (of a product)
Sodium D-isoascorbate	food grade	Zhucheng Huayuan Biological Engineering Co.
Compound Phosphate 2	food grade	Xuzhou Haicheng Food Additives Co.
Curdlan gel	CY-1 CY-2	Shandong Duiyuan Yikang Biotechnology Co.

2.2. Instruments And Equipment

Table 2. Main instrumentation

Instrument name	model number	factory owners
Electronic counting scales	ACS-30kg	Shanghai Ranhao Electronics Co.
electronic balance	HC2003	Cixi Huaxu Weighing Industry Co.
meat grinder	LG-SY6A	Zhongshan Liguo Electric Co.
SMS mass spectrometer (UK)	TA.XT Plus Type C	Stable Micro Systems, UK
induction cooker	C21-WT2121	Guangdong Midea Life Electric Appliance Manufacturing Co.

2.3. Experimental Methodology

2.3.1. Process flow

Raw meat → cutting → marinating → chopping → enema → punching air holes → steaming → cooling → finished product

2.3.2. Basic formulations

Beef tendon (or beef brisket) 1000g, 2% salt, 0.045% sodium D-isoascorbate, 0.25% compound phosphate, 2.5% sugar, 0.126% black pepper, 0.6% five-spice powder, 0.6% monosodium glutamate, 10% ice water.

2.3.3. Operational points

Select fresh beef and thaw the meat in a compartmentalised bag at room temperature under low running water. Remove connective tissue and cut the meat into cubes (10cm x 10cm x 10cm) and divide equally into 5 equal parts. Add salt, compound phosphate, and sodium D-isoascorbate, mix well, and marinate at room temperature. Put the marinated meat and ingredients together into a meat grinder for high-speed chopping, add ice water in stages during chopping, and control the temperature at 8-12 ℃ to complete the emulsification of the sausage. Use the manual enema to pour the minced meat into the enteric coating, and the enema process requires the minced meat to be evenly distributed in the meat sausage and the obvious air holes to be tied off. The enucleated emulsified sausage was put into a steamer and steamed under the power of 1600W of induction cooker, and then taken out and put into cold water to cool down to room temperature for spare use.

2.4. Experimental Design

2.4.1. One-factor experiment for optimisation of beef emulsified sausage process

(1) Cure time

The control cure times were: 30min, 60min, 90min, 120min and 150min.

(2) Chopping time

The control chopping time is: 5s, 10s, 15s, 20s, 25s.

(3) Steaming time

The controlled steaming times were: 30min, 35min, 40min, 45min, 50min.

2.4.2. Beef emulsified sausage process optimisation orthogonal test

On the basis of the one-way experiment, three factors, namely, cure time (A), chopping time (B) and steaming time (C), were selected for the three-factor, three-level orthogonal test using sensory scores as evaluation indexes. The levels of each factor in the orthogonal test are shown in Table 3.

Table 3. Levels of factors in orthogonal test

level	Curing time (A)	Chopping time (B)	Steaming time (C)
1	30min	15s	35min
2	60min	20s	40min
3	90min	25s	45min

2.4.3. Investigating the effect of different types of Curdlan gel on the texture of beef emulsified sausages

(1) Curdlan gel (CY-1)

The controlled additions of Curdlan gel (CY-1) were: 0%, 0.25%, 0.5%, 0.75% and 1%.

(2) Curdlan gel (CY-2)

The controlled additions of Curdlan gel (CY-2) were 0%, 0.25%, 0.5%, 0.75%, and 1%.

2.5. Measurement methods

2.5.1. Sensory evaluation

Referring to the criteria of Xin Zhang et al [11] with modifications, 10 students of food majors were randomly invited to be sensory assessors to evaluate the sensory evaluation of the colour, tissue state, taste, mouthfeel, and overall acceptability of beef emulsified sausage, with a maximum of 20 points for each index and a minimum of 0 points out of a total of 100 points. Their scoring criteria are shown in Table 4.

Table 4. Sensory scoring criteria for beef emulsified sausage

sports event	Evaluation criteria	Sensory score
colour	Normal colour, no bad colour	14-20
	Colour is more normal, slightly darker	7-13
	Colour dullness is severe	0-6
Organisational status	Smooth cut, fine texture	14-20
	Smoother cut surface, finer texture	7-13
	Rough cut, rough texture	0-6
flavours	Salty, light, fresh and flavourful	14-20
	Saltier or lighter in flavour	7-13
	Too salty or too light in flavour	0-6
how food feels in the mouth	Easily chewed, no graininess or woodiness	14-20
	Easier to chew, with a slight grainy and woody feel	7-13
	Rough mouthfeel, heavily wooded	0-6
Overall acceptability	ideal	14-20
	preferable	7-13
	Very unsatisfactory.	0-6

2.5.2. Texture determination

A texture analyser can accurately quantify the textural properties of food products and determine the quality characteristics of food products with high precision [12]. The TPA test can provide a large amount of information on texture characteristics obtained from the double compression test [13]. The TPA test provides a wealth of information on textural characteristics obtained from double compression testing [14]. The TPA test can provide a large amount of information on texture characteristics obtained from the double compression test. The method of Yimin Yu et al [15] the method of Yi-Min Yu et al. was modified to determine the texture of emulsified sausages using a texture meter, and the texture profile analysis method was chosen as the measurement method. The enteric coating was removed and the emulsified intestines were cut into cubes of 15 mm × 15 mm × 15 mm for measurement. The measurement parameters were as follows: probe type P36R, pre-test rate of 2.0 mm/s, test rate of 1.0 mm/s, post-test rate of 1.0 mm/s, specimen strain of 40%, initiating force of 5 g, and intermediate cycle recoverable time of 5 s. Five parameters of hardness, resilence, cohesion, springiness and chewiness were selected as the analysis indexes, and four parallel tests were repeated for each group of samples.

2.6. Data processing

Data were analysed and processed using SPSS 26.0 and Origin 2019.

3. ANALYSIS OF RESULTS

3.1. Analysis Of The Results Of The Optimisation Of The Beef Emulsified Sausage Process

3.1.1. Determination of cure time

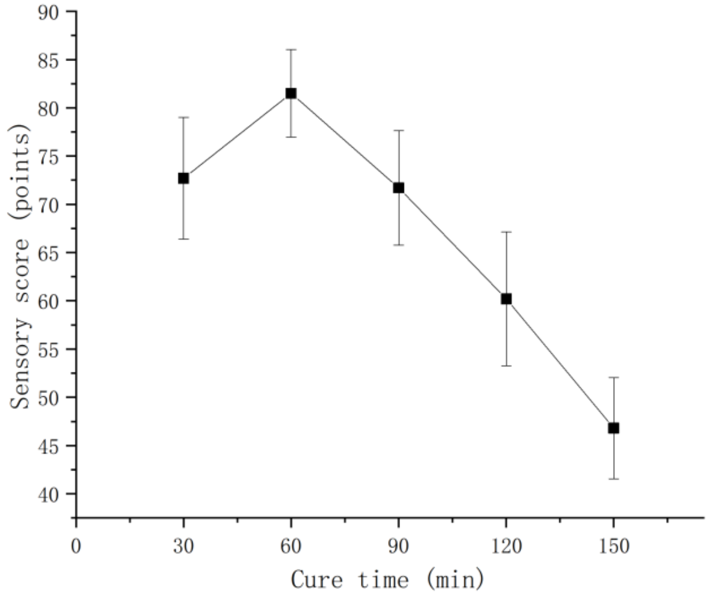


Figure 1. Effect of cure time on sensory scores

The highest sensory score of 81.5 was obtained when the cure time was 60 min, which had a significant advantage over the scores of other time points. When the curing time exceeded 90 min, we found that the salty flavour of the emulsified sausages gradually increased with increasing curing time, which led to a significant decrease in sensory quality. Considering this relationship between curing time and sensory quality, 60 min was selected as the optimal curing time for subsequent experiments.

3.1.2. Determination of chopping time

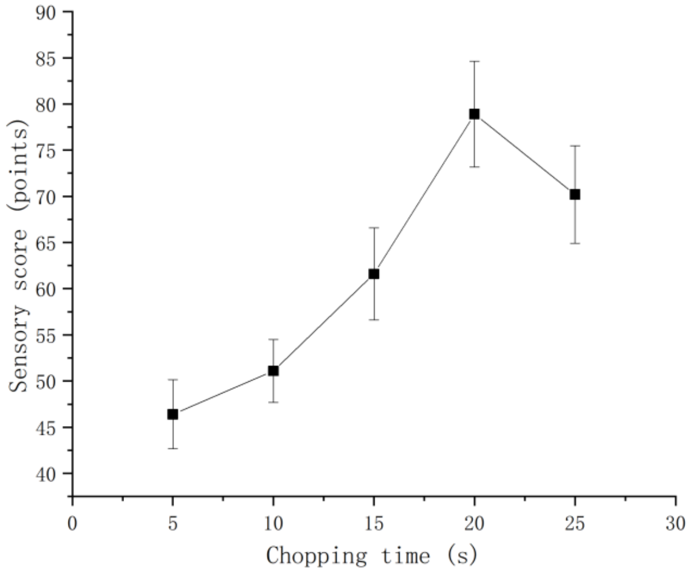


Figure 2. Effect of chopping time on sensory scores

Chopping process has a great influence on the yield and quality of low temperature meat products [16, 17] Jin [18] Jin, Lee [19] et al. found that as the chopping time increased, the rate of myogenin dissolution increased and the oxidation of myoglobin increased, affecting the colour of emulsified sausages. The highest sensory score of 78.9 was obtained when the chopping time was 20s. When the chopping time was too short, the resulting emulsified sausage had a rough cut of tissue state, rough texture and taste, and with the increase of chopping time, the emulsified sausage tissue state and taste scores increased, and the sensory quality increased. Chopping time of 20 s was chosen for the subsequent experiments.

3.1.3. Determination of steaming time

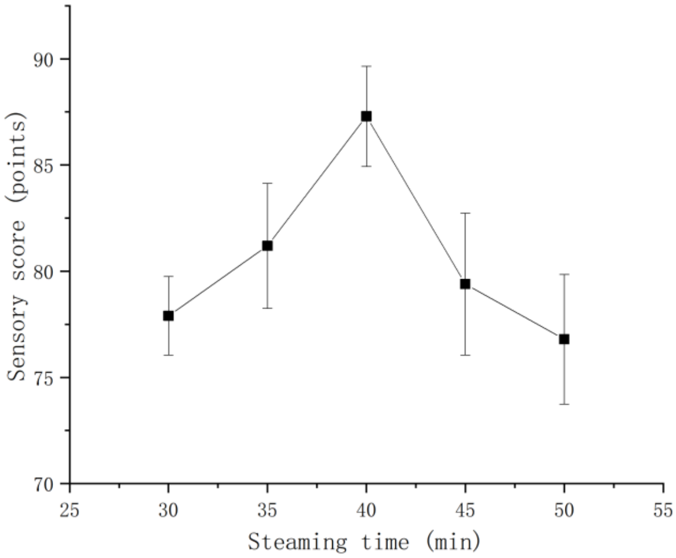


Figure 3. Effect of steaming time on sensory scores

The highest sensory score of 87.3 was obtained when the steaming time was 40 min and this score was significantly higher than the scores at other time points. The steaming time had an effect on the texture of beef emulsified sausage. If the steaming time was too long, the beef emulsified sausages would become inelastic, while too short a steaming time might result in the beef emulsified sausages not being fully cooked and having a raw texture. Both situations would reduce the overall acceptability of beef emulsified sausages. Therefore, in order to ensure the quality and taste of beef emulsified sausages, 40 min was selected as the optimal steaming time.

3.1.4. Analysis of the results of orthogonal test for optimisation of beef emulsified sausage process

Table 5. Results of orthogonal test for beef emulsified sausage process optimisation

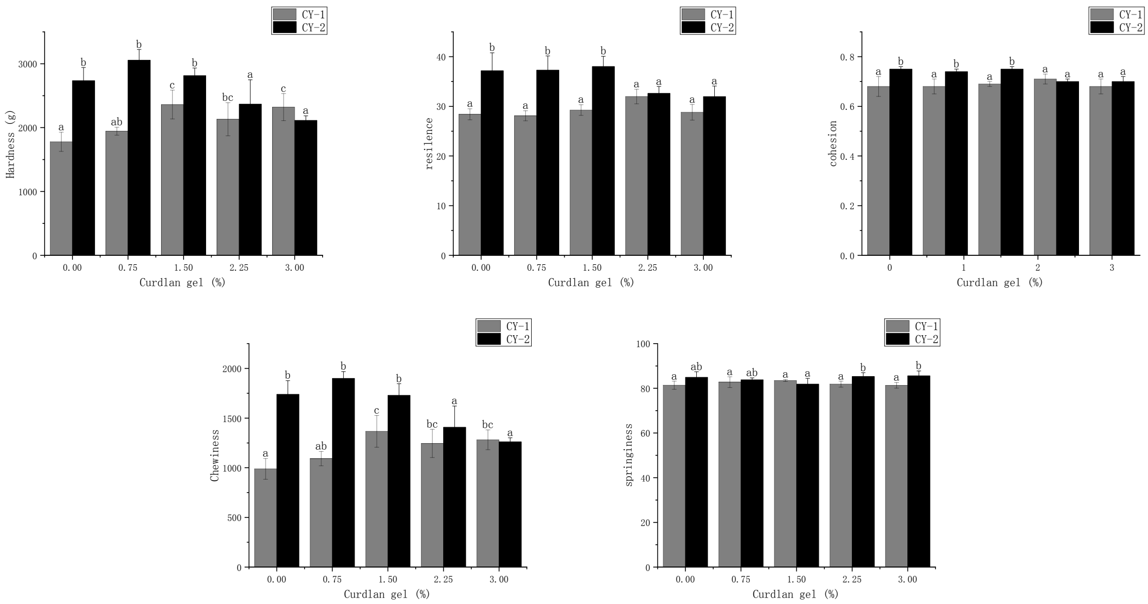
process number	A	B	C	blank column	Sensory score
1	3	2	3	1	69
2	3	3	1	2	67
3	2	1	3	2	68
4	2	3	2	1	87
5	2	2	1	3	88
6	1	3	3	3	66
7	1	1	1	1	54
8	3	1	2	3	55
9	1	2	2	2	73
k1	64.33	59.00	69.667		
k2	81.00	76.67	71.667		
k3	63.67	73.33	67.667		
R	17.33	17.67	4		

Analysing and exploring the results of orthogonal tests (Table 5), the extent of influence of different factors on the processing of beef emulsified sausage can be clearly seen. The results showed that factor B, chopping time, was the most important factor affecting the quality of beef emulsified sausage processing. The control of chopping time plays a crucial role in the texture, mouthfeel and final flavour of beef emulsified sausage, followed by factor A, cure time, which plays a key role in the formation of flavour and texture of beef emulsified sausage. Finally, factor C, extraction time, has less influence than the first two factors. The relationship between these three factors is B>A>C, i.e. chopping time is the most critical, followed by cure time and finally extraction time.

After analysis and comparison, the flavour and texture of beef emulsified sausage can be maximized when the cure time is 60 min, the chopping time is 20 s and the steaming time is 40 min, i.e., the combination of A_2 B_2 C_2 process. This combination not only enables the beef emulsified sausage to better absorb the seasonings and form rich layers during processing, but also ensures that the sausage body achieves the best taste and texture during steaming. Validation tests were conducted to further verify the effectiveness of this optimal combination. After strictly following this process combination, beef emulsified sausages were obtained with an organoleptic score of 88. This result demonstrated that the combination of cure time of 60 min, chopping time of 20 s and steaming time of 40 min was indeed the optimal choice for beef emulsified sausage processing.

In summary, through in-depth analysis of the results of single-factor experiments and orthogonal tests, the optimal process combination for beef emulsified sausage processing was finally determined as A_2 B_2 C_2 , i.e. curing time of 60 min, chopping time of 20 s, and steaming time of 40 min, and its validity and reliability were proved through validation tests.

3.2. Effect Of Different Types Of Kojic Acid Gum And The Amount Of Addition On The Texture Of Beef Emulsified Sausage



Note: Beef emulsified sausage with CY-1 type Curdlan gel is made from beef brisket, and beef emulsified sausage with CY-2 type Curdlan gel is made from beef tendon.

Figure 4. Effects of different types and amounts of Curdlan gel on the texture of beef emulsified sausages

As shown in Figure 4, with the gradual increase of the addition amount of CY-1 model Curdlan gel to the beef emulsified sausages, the three key indexes, hardness, springiness and chewiness, initially showed an increasing trend with the addition of Curdlan gel. These textural properties were at their highest when the addition amount reached 1.5%, at which point the beef emulsified sausages showed a significant ($P<0.05$) increase in hardness and chewiness compared to the blank group and the sample group with an addition amount of 0.75%, which is consistent with the results of Kimura et al [20] and Lee et al [21], where myofibrillar fibrillar proteins in the minced meat were denatured during heating of emulsified sausages, and surface activity Curdlan gel, also known as gel polysaccharide, interacts with myofibrillar fibrillar proteins to make the reticulation more compact and stable, which improves the gel strength of myofibrillar fibrillar proteins and increases the hardness, springiness, and chewiness of emulsified sausages [22]. However, when the addition of Curdlan gel continued to increase to 2.25%, a certain degree of decrease in the hardness, springiness and chewiness of beef emulsified sausage was observed, and this change, although present, was not significant ($P>0.05$), implying that the changes in the texture of the product were still within an acceptable range at this addition level. When the additive amount was further increased to 3%, the hardness and chewiness showed a certain degree of recovery, but this recovery was not significant ($P>0.05$), indicating that the effect of Curdlan gel on the texture of beef emulsified sausage began to weaken at high additive amount, on the other hand, the two texture indexes, resilence and cohesion, also showed different The trend of change. The resilience and cohesion showed a tendency of increasing and then decreasing with the increase of the added amount. When the addition amount of Curdlan gel reached 2.25%, the resilience and cohesion reached the highest value, and even though these two indexes decreased in higher addition amounts thereafter, this decrease was not significant ($P>0.05$) and was still higher than that of the blank group, indicating that the textural stability of the product still remained relatively good in this addition amount range, which is in agreement with the results of the study conducted by Zhao Chunbo et al [9]. It is worth noting that the beef emulsified sausages with CY-1 Curdlan gel were improved in all textural properties compared with the blank group. This indicates that the addition of CY-1 model Curdlan gel played a positive role in improving the textural properties of beef emulsified sausages.

The effect of CY-2 type Curdlan gel on the textural properties of beef emulsified sausage was different. The hardness, resilence and chewiness of beef emulsified sausages showed an increasing and then decreasing trend with the increase of CY-2 Curdlan gel addition, which was consistent with the findings of Jiang Shuai et al [22]. The hardness and chewiness of emulsified sausage reached the highest when the added amount was 0.75%, and the resilence of emulsified sausage reached the highest when the added amount was increased to 1.5%. However, these changes were not significant ($P>0.05$) when compared to the blank group. When the addition amount was 1.5%, hardness and chewiness decreased but were still higher than the blank group. However, when the addition amount of Curdlan gel of CY-2 model was further increased to 2.25% and 3%, the hardness, resilence and chewiness showed significant ($P<0.05$) decrease and were lower than the blank group. This implies that CY-2 model Curdlan gel adversely affected the textural properties of beef emulsified sausage at high addition levels. Meanwhile, the cohesion of beef emulsified sausage showed a decreasing, then increasing and then decreasing trend with the increase of CY-2 model Curdlan gel addition. The cohesion reached the highest when the additive amount was 1.5%, but it decreased significantly ($P<0.05$) and was lower than that of the blank group as the additive amount continued to increase. This indicated that the negative effect of CY-2 model Curdlan gel on cohesion was gradually highlighted at high addition levels.HU Y et al [23] pointed out that the molecular structure of Curdlan gel's own helix can absorb 100 times its own mass of water, which can lead to the destruction of the textural properties of minced meat. For springiness, which is a textural index, it showed a decreasing and then increasing trend as the amount of Curdlan gel added to the CY-2 model was increased. The decrease in springiness was not significant ($P>0.05$) at addition levels of 0.75% and 1.5%. However, when the addition amount reached 2.25% to 3%, the springiness increased significantly ($P<0.05$) and was higher than that of the blank group. Among them, the highest value of springiness was reached when the addition amount was 3%. This suggests that the CY-2 model Curdlan gel plays a positive role in the improvement of springiness at high addition amounts.

In the taste of beef emulsified sausage, it is not that the higher the values of hardness and chewiness are the better, too high will lead to chewing difficulties, which is not easy to be accepted organoleptically, and the smaller the values of hardness and chewiness are, the smaller the force required for chewing, and the better the taste of the product will be [24]. In summary, we can draw the following conclusions: when the addition amount of Curdlan gel is higher than 2.25%, the enhancement effect of CY-1 type Curdlan gel on the textural properties of beef emulsified sausage begins to weaken; while CY-2 type Curdlan gel reduces the textural properties of beef emulsified sausage. Therefore, in order to ensure that the textural properties of the beef emulsified sausage are optimal and the organoleptic properties of the sausage have the best palatability, it is recommended that the additive amount of Curdlan gel of CY-1 type be controlled between 1.5% and 2.25%, and the additive amount of Curdlan gel of CY-2 type be controlled between 0.75% and 1.5%. This dosage range can give full play to the effect of Curdlan gel on the texture of beef emulsified sausage and avoid the negative effect of too high dosage.

4. CONCLUSION AND OUTLOOK

In this experiment, fresh beef tendon and beef brisket were used as raw materials, and the effects of cure time, chopping time and steaming time on the sensory quality of beef emulsified sausage were firstly investigated and analysed by one-way and orthogonal tests, and the optimal process combination of beef emulsified sausage was finally determined as $A_2B_2C_2$, i.e., the cure time was 60min, the chopping time was 20s, and the steaming time was 40min, and then the effects of adding different types of cortisone on the textural characteristics of beef emulsified sausage were investigated on the basis of the process combination. Then, on the basis of this process combination, the effects of adding different types of Curdlan gel on the textural properties of beef emulsified sausage were investigated, and it was finally concluded that good textural properties of beef emulsified sausage could be produced with the additive amount of CY-1 Curdlan gel ranging from 1.5% to 2.25%, and the additive amount of CY-2 Curdlan gel ranging from 0.75% to 1.5%. The model provides a certain reference for the production and improvement of beef emulsified sausage.

Curdlan gel, as a natural polysaccharide food ingredient, has excellent gel properties and stability, and thus has been widely used in the food industry. At present, research on the application of Curdlan gel in beef emulsified sausage has made some progress. It is shown that Curdlan gel can effectively improve the texture and taste of beef emulsified sausage, making it more delicate, soft and elastic. At the same time, Curdlan gel can also improve the water retention of emulsified sausage and reduce water loss, thus prolonging the shelf life of the product [25]. In addition, Curdlan gel has good thermal stability and acid resistance, which can maintain a stable gel structure under high temperature and acidic environment, providing better conditions for the processing of beef emulsified sausage.

However, there are still some problems in the current research on the application of Curdlan gel in beef emulsified sausage. Firstly, the effect of the added amount of Curdlan gel on the texture and taste of the product needs further research. Secondly, the interaction between Curdlan gel and other additives also needs to be further explored in order to optimise the formulation and process of the product. In addition, the effect of Curdlan gel on the nutrient composition and digestibility of beef emulsified sausage needs to be studied in depth to assess its impact on human health. In conclusion, the application of Curdlan gel in beef emulsified sausage has great prospects and potential. Through in-depth research and process optimisation, the quality and stability of beef emulsified sausages can be further improved to meet consumer demands and promote the sustainable development of the meat industry.

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