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The Effect of Soy Protein Isolate, Starch and Salt on Quality of Ready-to-Eat Restructured Beef Products

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Abstract: This experiment explored the effects of different additions of soy protein isolate, starch and salt on the quality characteristics of the ready-to-eat restructured beef products. The ground beef was used as the experimental material, and the different soy protein isolates, starch and salt were studied after conditioning and recombination. The product has the characteristics of thawing loss, yield, bond strength, texture and other quality characteristics. The results show that with the increase of the amount of soy protein isolate, the indicators of the products were improved, but when the amount of soy protein isolate was more than 2%, the products showed a bean flavor and white streaks, so the final addition of soy protein isolate was not more than 2%; similar to the soy protein isolate, the amount of starch added did not exceed 2%; with the increase of salt addition, the product's various indicators have been improved, but when the salt addition amount exceeds 1.5%, the products was too salty, so the final optimum amount of salt was 1.5%.

Keywords: Soy Protein Isolate, Starch, Salt, Ready-to-Eat Restructured Beef Products

1. Introduction

Due to the improvement of the quality of life and the accelerated pace of life, people are paying more and more attention to the convenience, nutrition and safety of meat products while increasing the demand for meat products [1]. At the same time, a large amount of scrap meat, minced meat and minced meat produced in the production of meat products are not effectively utilized, which pollutes the environment while wasting a large amount of animal protein, causing huge economic losses. If it is reorganized while adding certain nutrients, it can save costs and increase meat utilization, while producing safe, healthy and nutritious meat products. Ready-to-eat restructured beef products refers to the use of ground beef, scrap meat, and deboned beef as raw materials, adding appropriate binders and seasonings or nutrients, and processing such as pickling, rolling, molding, etc., in the form of packaging or bulk. Transportation, storage and sale under low temperature freezing or refrigerating conditions, a type of meat product that consumers can use directly or simply heat-treated [2]. The ready-to-eat restructured beef products combines the processing technology of both conditioned beef products and recombinant beef products, and has the product characteristics of both of products. It also avoids the tedium and boredom caused by long-term consumption of a single variety of meat products, satisfies people's growing consumption needs, and opens up new outlets for enterprise production.

Soy protein isolate (SPI), starch and salt. have a very significant effect on the improvement of meat quality and water retention performance. SPI and starch have strong water absorption capacity and gel properties, active groups and muscle proteins in soy protein isolate. The interaction between them forms a more stable gel network structure that retains more moisture. Thereby improving the water retention of the meat product. Salt can act on the meat protein system, thereby increasing the amount of myofibrillar protein, promoting the cross-linking between protein polypeptide chains, enhancing the interaction between proteins, and forming a stable three-dimensional network structure, thereby improving The role of texture characteristics such as hardness and chewiness of meat products.

The main purpose of this experiment was to investigate the effects of different added amounts of SPI, starch and salt on the quality characteristics of the conditioned recombinant beef products. In the process of conditioning the recombinant beef, different amounts of SPI, starch and salt were added. Investigate the effects of these three substances on the thawing loss, color difference, texture, water distribution and sensory quality of the ready-to-eat restructured beef products, so as to determine the optimum addition amount in the ready-to-eat restructured beef products, and provide for the subsequent processing and industrialization of the processed beef products. Theoretical guidance and technical support.

2. Materials and Methods

2.1. Materials and Equipment

Minced beef purchased in Harbin Trust-Mart; Compound Phosphate Heilongjiang Fengda Food Ingredients Co. Ltd; Salt Salt in Heilongjiang Salt Industry Group Co. Ltd; Transglutaminase Taixing Yiming Biological Products Co. Ltd; Sodium caseinate, Beijing billion Connaught Food Ingredients Co. Ltd; konjac powder Heze City, Shandong Province, poor Ni Ltd. Xanthan gum Henan Tianguan Biological Engineering Co. Ltd; histidine, lysine Zhengzhou Bo-Biological Technology Co. Ltd.

JD500-2 electronic balance Shenyang Longteng Electronic Weighing Instrument Co. Ltd.; WSC-S-type color measurement instrument Shanghai Physical Optical Instrument Factory; TA-XT plus texture analyzer British Stable Micro System; A/SPR-type adapter probe, Forming mold College of Food Science Northeast Agricultural University homemade, specifications for the 15cm × 9cm × 10cm; MC-SH2115 Induction Cooker Guangzhou Midea Life Electric Manufacturing Co. Ltd. SANYO-SOB150 Oven Japan Sanyo Electric Co., Ltd. Mq-20 Low Field Nuclear Magnetic Resonance Analysis Germany Brock Company

2.2. Method

2.2.1. Conditioning Ready-to-Eat Restructured Beef Products

i. Conditioning the basic formula of ready-to-eat restructured beef.

Minced beef block 1000g, added auxiliary materials: 0.5% of gelatin, 0.5% of cumin grain, 0.3% of white pepper powder, 0.3% of cumin powder, 0.3% of chili powder, 0.05% of pepper powder, 0.05% of cinnamon powder, 0.05%, ginger powder 0.1%, sesame oil 1.5%, composite phosphate 0.3%, according to our previous experimental results using a binder (transglutaminase: sodium caseinate =1: 4) 1.2% [3], Composite edible glue (konjac powder: xanthan gum =6: 4) 0.4% [4], water 6% [5].

ii. The operating point.

Take 1000g ground beef, cut into about 1cm pieces of meat, the binder, compound food gum and other seasoning materials and water mixed evenly added to the ground beef, fully mixed into the mold. The mold into the 4°C refrigerator reaction 4h, and then placed in -18°C freezer overnight. The meat samples were taken out in 4°C environment 4h slowed to the center temperature of 0°C when sliced, sliced meat is completely baked after the finished product.

2.2.2. Experimental Design

The other process conditions and experimental formula were fixed, and the single factor test was carried out on the addition amount of SPI, starch and salt respectively. Six groups of samples were taken, and 0 g/100 g was added as control, and 1.0 g /100g, 1.5 g/100g, 2.0 g/100g, 2.5 g/100g and 3.0 g/100g of SPI was added to the experimental group.; 1.0 g/100g, 1.5 g/100g, 2.0 g/100g, 2.5 g/100g and 3.0 g/100g of starch was added to the experimental group.; 0.5 g / 100 g, 1.0 g / 100g, 1.5 g / 100g, 2.0 g / 100g and 2.5 g / 100g of salt was added to the experimental group, according to the process of making meat samples for the determination of product indicators.

2.3. Determination of Indicators

2.3.1. Determination of Moisture Distribution by LF-NMR (Measurement of T_2)

According to the method of Aursand et al. with a slight modification, the formed recombinant meat sample was put in a dedicated test tube (tube diameter 1.8 cm, height 18 cm), magnetic field strength of 0.47T, proton resonance frequency of 20MHz. T_2 in meat samples was determined using the Carr-Purcell-Meiboom-Gill (CPMG) program. For each sample measurement, the program automatically scanned 16 times, each scan repeat interval of 2s. The T_2 of each sample after the determination was inverted by CONTIN software and the corresponding relaxation times (T_{2b}, T_{21} and T_{22}) were reflected [6].

2.3.2. Determination of Bond Strength

According to the method of Romero et al., some changes were made. The frozen meat samples were taken out to slow down until the central temperature was 0°C (9cm × 2cm × 0.5cm), A/SPR probe tensile test, the texture of the arm set to 25kg, the test speed of 1.0mm/s, before and after testing the speed of 2.0mm/s, the test mode for the tension, the sensing force of 5g, the fracture induction of 20g. The probe begins to move upward, recording the maximum pulling force F (N) required to pull the broken meat stick [7].

$$\text{Bond Strength (g/cm2)} = \text{F/S} \tag{1}$$

Where: F is the maximum force required to pull off the meat; S is the cross-sectional area of the meat.

2.3.3. Determination of Color

According to the method of Kayaardi et al. and slightly modified. The recombinant beef was cut into 4 cm×4 cm×2cm pieces and measured by WSC-E color difference meter in fresh state and cooked state respectively. Whiteboard chromaticity values L^* were 96.22, a^* was 6.03 and b^* was 15.06. The O/D test head is used to determine the color difference of the sample. L^*, a^*, b^* represent the brightness value, redness value and yellowness value of the sample respectively [8].

2.3.4. Determination of Water Activity (aw)

Open the AquaLab water activity meter and preheated for about 20 minutes, about 2.0g of mitigated recombinant meat were pieced cut and tiled in a dedicated water activity measuring dish (at least covered the bottom layer), Open the sample box and lided into the sample cell, tighten the sample cell cover, turn on the power, when the reading is stable, read directly from the display sample water activity.

2.3.5. Texture Profile Analysis, TPA Test

Reference Pietrasik et al method and make appropriate changes, after baking, the texture of samples were directly determined, each sample to do 8 parallel samples, texture instrument parameters set to pressure, the determination parameters: before testing speed 5mm/s, test speed and speed after testing 2mm/s, the P/50 probe was uesd, the probe diameter is 5cm. Measurement results mainly take hardness, springiness, chewiness sand cohesiveness of which hardness and chewiness in grams (g) said [9].

2.3.6. Determination of Thawing Loss and Yield

Thawing loss (TL) was determined according to the method of Serrano et al with appropriate modifications. The frozen meat samples were cut into pieces of size 3cm×3cm×2 cm and weighed the mass (m_1), placed in 20°C environment 15min mitigation, to be completely mitigated, with filter paper sucked the surface of the meat moisture, again called the mass (m_2) [10].

$$TL/\% = (m1 - m2)/m1 \times 100 \quad (2)$$

Where: m_1 is the quality before thawing; m_2 is the quality after thawing.

The yield was determined according to the method of Gök et al. with appropriate modifications[11]. The sliced recombinant beef samples were roasted in an oven and weighed the mass before roasting (W_1) and the mass after roasting (W_2), The test samples to maintain the same size, each test to ensure that the number of samples is basically the same. Yield according to equation (3) to calculate:

$$\text{yield}/\% = W2/W1 \times 100 \quad (3)$$

Where: W1 is the quality before baking; W2 is the quality after baking.

2.3.7. Sensory Evaluation

Sensory evaluation refers to the method of Geli et al. and make some appropriate changes to make a sensory score for cooked meats. 10 postgraduates engaged in food majors were invited to made up the assessment team and tested by double-blind method [12]. Mainly on the product color, odor, status, taste and overall acceptability of assessment, each indicator of the highest score of 9 points and the minimum of 1 point, according to the score to determine the merits of the sample.

Color 9 is divided into product reddish brown luster, an appetite, 1 is divided into dark red color, dull, poor appetite; odor 9 is divided into meat smell prominent, 1 is very light meat smell or none; status 9 points into a complete piece of meat, uniform thickness, meat is closely without raw, 1 is divided into pieces of meat is not dense, inelastic, green films; taste 9 is divided into delicate meat, chewy and aftertaste, 1 minute hardwood firewood feeling, less aftertaste; overall acceptance of 9 points for acceptability, loved by consumers, 1 point is poorly accepted, the consumer is difficult to accept.

2.4. Statistics Analysis

Each treatment is repeated three times and the results are expressed as mean ± standard deviation. Statistical analysis was performed using the Linear Models program in Statistix 8.1 software with significant differences ($P < 0.05$). Analysis was performed using the Tukey HSD program and plotted using Sigmaplot 12.0 software.

3. Results

3.1. Effects of SPI, Starch and Salt on Thawing Loss and Yield of the Ready-to-eat Restructured Beef Products

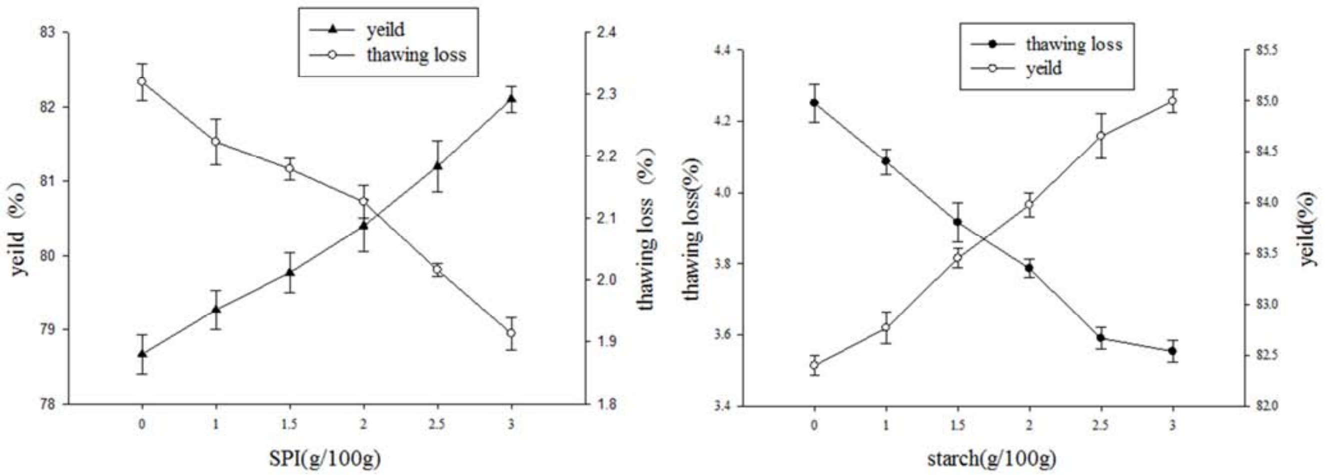

Figure 1. *Influences of soy protein isolate and Starch level on thawing loss and product yield.*

It can be seen from Figure 1 that with the increase of SPI level, the thawing loss of the product gradually decreased and the yield was significantly increased ($P < 0.05$). The thawing loss and yield of the product are closely related to the water retention of the meat product, which indicated that with the increase of the SPI, the water retention capacity of the product was gradually enhanced ($P < 0.05$), which may be due to the SPI has the strong water absorption capacity and gel properties, the interaction between the active groups of the SPI and muscle proteins form a more stable gel network structure which retaining more moisture [13]. Thereby improving the water retention of the meat product.

It can be seen from Figure 1 that the amount of starch added has a significant effect on the thawing loss and yield of the product ($P < 0.05$). With the increase of starch addition, the thawing loss of the product decreases significantly and the yield rate increases remarkably. This may be due to the fact that the starch granules swell and absorb water, and on the other hand may be the result of water absorption, swelling, gelatinization of the starch during heating. Since the starch gelatinization temperature is higher than the denaturation temperature of the muscle protein, when the starch is gelatinized, the muscle protein has substantially undergone denaturation and forms a three-dimensional network structure. At this time, the gelatinized starch granules will take up the moisture which is not tightly bound in the network structure, and this part of the water is fixed by the starch granules without being lost by heating, so the water holding property is improved, and the water content is reduced. At the same time, when heated, the starch granules can also absorb the fat dissolved into liquid, thereby reducing the loss of fat and increasing the yield [14].

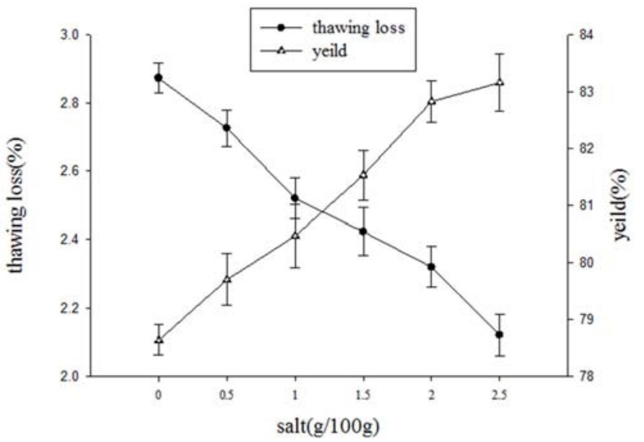

Figure 2. Influences of different salt level on thawing loss and product yield.

The effect of different salt addition on the thawing loss and yield of the product was shown in Figure 2. The addition of different concentrations of salt had a significant effect on the thawing loss and yield of the product ($P < 0.05$), with the increase of salt addition. The thawing loss of the product gradually decreased from about 2.9% when the amount of addition was 0 g/100g to about 2.1% when the amount was 2.5 g/100g. The yield of the product increased from about 78.5% at the added amount of 0 g/100g to about 83.2% at the added amount of 2.5 g/100g. The thawing loss of the product was significantly reduced and the yield was significantly improved. This may be due to the fact that as the amount of salt added increases, the water retention of the product was gradually increases, and more moisture was locked during processing, which reduces the thawing loss and increases the yield [15].

3.2. Effects of SPI, Starch and Salt on the Bonding Strength and Water Activity of the Ready-to-eat Restructured Beef Products

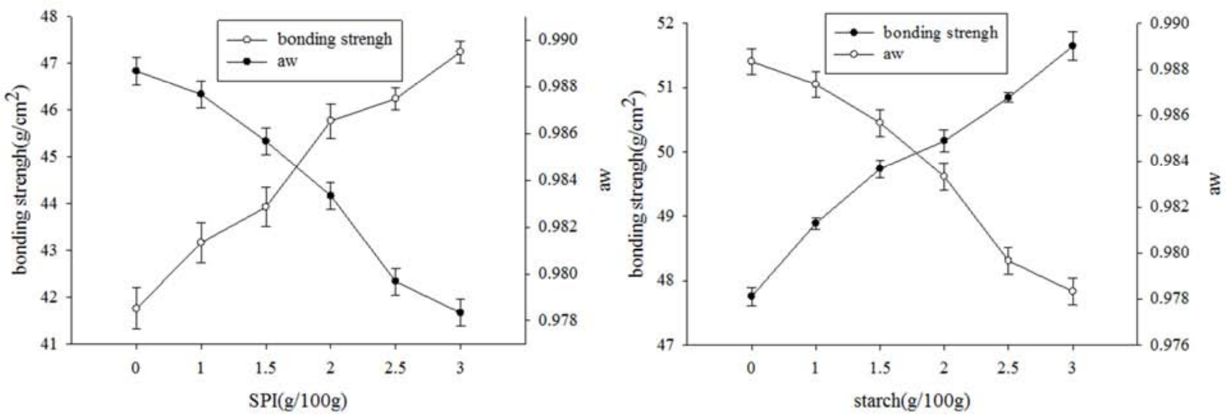

Figure 3. Influences of different level of SPI and starch on product bonding strength and water activity.

It can be seen from Figure 3 that with the increase of the amount of soy protein isolate added, the bond strength of the product gradually increased ($P < 0.05$). This may be due to the gelling properties of soy protein isolate, which crosslinks soy protein with meat protein to form a more stable three-dimensional gel network structure, which increases the adhesion of meat products; In addition, the mixture of soy protein isolate and water has a certain viscosity, and the higher the concentration of soy protein isolate, the greater the viscosity of the mixture, The mixture adheres to the surface of the meat to act as a binder, which enhances the bonding strength [16].

It can be seen from Figure 3 that the amount of starch added has a significant effect on the bond strength and water activity of the product (P < 0.05). As the amount of starch added increases, the bond strength of the product increases significantly and the water activity decreases significantly. This may be due to the swelling of the starch granules, which form a viscous colloid which covers the surface of the meat and acts to increase the viscosity of the meat.

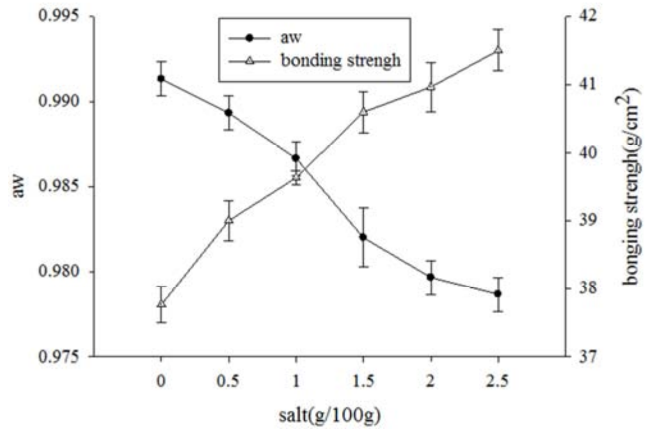

Figure 4. *Influences of different salt level on binding strength and* a_w.

It can be seen from Figure 4 that the different salt addition amount has a significant influence on the bond strength and water activity of the product (P < 0.05). As the amount of salt added increases, the bond strength of the product increases and the water activity decreases significantly. This may be due to the addition of salt, which causes the myofibril to swell, a large amount of chloride ions were bound to the myofibrils, and sodium ions formed an ion cloud around the myofilament to wrap it. When actin swells, myosin was separated from myofibrillar protein, forming a viscous exudate on the surface of the meat, which fixes the free water, thereby enhancing the adhesion and water holding capacity of the meat [17]. At the same time, the electrostatic repulsion caused by the negative charge increases, and the ionic strength of the meat increases. Therefore, the dissolution amount of myofibrillar protein in the meat product was increased, and the emulsifying ability was improved, thereby forming a better and tighter three-dimensional network structure in the system, then the bonding strength of the product was improved and the binding force to water was enhanced. So water retention of meat products was Increased [18].

3.3. Effects of SPI, Starch and Salt on Water Distribution of the Ready-to-Eat Restructured Beef Products

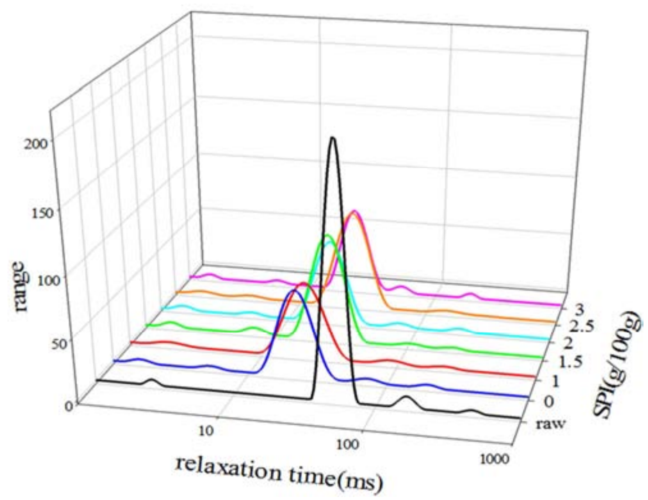

Figure 5. *Representative distributions of* T_2 *relaxation times for different SPI addition.*

It can be seen from Figure 5 that the amount of SPI has a significant effect on the T_2 relaxation time distribution (P < 0.05). The T_2 relaxation time after LF-NMR attenuation curve fitting was mainly distributed as three peaks, which represent the three water existence states: combined water (T_{2b}), non-flowable water (T_{21}) and free water (T_{22}) [19]. Compared with fresh meat, as the amount of SPI increased, the peaks representing the three different states of water gradually shifted to left, which indicating that the relaxation time became shorter, the mobility of water molecules weakened. The combination of water molecules and meat proteins was enhanced, and the water holding capacity of meat products was enhanced [20]. Compared with fresh meat, the area of water relaxation peak in each state of the experimental group with soy protein isolate was significantly decreased (P < 0.05), and the peak area of the non-flowable water peak was the most obvious.

Table 1. *Influences of different SPI level on* T_2 *relaxation times.*

SPI (g/100g)	T_{2b} (ms)	T_{21} (ms)	T_{22} (ms)
raw	2.53 ± 0.06^{A}	51.30 ± 0.11^{A}	180.00 ± 10.05^{D}
0	1.93 ± 0.06^{B}	25.16 ± 0.55^{B}	224.34 ± 6.02^{A}
1.0	1.73 ± 0.05^{C}	23.23 ± 0.20^{C}	214.65 ± 6.10^{AB}
1.5	1.65 ± 0.07^{CD}	22.44 ± 0.21^{CD}	205.32 ± 5.17^{BC}
2.0	1.60 ± 0.02^{CD}	21.93 ± 0.16^{DE}	192.67 ± 3.54^{CD}
2.5	1.53 ± 0.06^{DE}	21.10 ± 0.27^{E}	190.67 ± 5.17^{CD}
3.0	1.41 ± 0.12^{E}	20.99 ± 0.63^{E}	182.66 ± 3.10^{D}

Note: A-E in the same column of letters, the same difference is not significant (P > 0.05), the difference is significant (P < 0.05).

The effect of the amount of SPI added on the T_2 relaxation time of the product is shown in Table 1. It can be seen from the table that the addition of different SPI had a significant effect on the T_2 relaxation time of the product (P < 0.05). Compared with fresh meat, the T_{2b} and T_{21} of each experimental group added with soy protein isolate were decreased significantly.

And with the increase of the amount of SPI, the relaxation time of bound water and non-flowable water decreased significantly, indicating that the relaxation time of combined water and non-flowable water were significantly shortened ($P < 0.05$). The binding of protein-like proteins was getting closer and closer. This may be due to the emulsification properties of SPI. SPI was a surfactant that lowers the surface tension of water and oil while lowering the surface tension of water and air, so it was easier to form a more stable emulsion. With the increase of the amount of SPI added, the emulsifying ability of the system is strengthened, and the water absorption capacity of soy protein isolate was gradually enhanced. The binding degree of bound water and non-flowable water to meat protein was more and more tightly, and the relaxation time becomed shorter [21]. In addition, as the amount of soy protein isolate added increases, the relaxation time of free water was significantly prolonged. This might be because that this part water was free of extracellular. After adding SPI, this part of the water was encapsulated by soy protein isolate particles, which makes the mobility weakened, loosens with meat protein, and prolongs relaxation time.

Table 2. *Influences of different SPI level on T_2 peak area fraction.*

SPI (g/100g)	A_{2b} (%)	A_{21} (%)	A_{22} (%)
raw	5.34±0.58^{BC}	204.31±5.13^{A}	8.67±1.15^{A}
0	3.02±0.09^{E}	63.35±5.51^{E}	6.30±0.58^{B}
1.0	3.67±0.58^{DE}	69.67±0.56^{DE}	5.33±0.56^{BC}
1.5	4.67±0.58^{CD}	74.00±3.47^{CD}	4.32±0.58^{CD}
2.0	5.00±0.05^{C}	80.10±1.15^{BC}	4.06±0.09^{CD}
2.5	6.33±0.58^{AB}	82.34±1.52^{BC}	2.67±0.58^{DE}
3.0	7.10±0.09^{A}	86.39±1.53^{B}	2.10±0.08^{E}

Note: A-E in the same column of letters, the same difference is not significant ($P > 0.05$), the difference is significant ($P < 0.05$).

The effect of different SPI on the percentage of the T_2 relaxation peak area of the product is shown in Table 2. It can be seen from the table that compared with fresh meat, the area of the easily-running water relaxation peak of each experimental group was significantly reduced ($P < 0.05$). This may be due to the salting or other excipients, which increases the osmotic pressure inside the cells and affects the distribution of hydrogen ions. In addition, with the increase of the amount of SPI added, the peak area percentage of bound water and non-flowable water increased significantly ($P < 0.05$), and the peak area percentage of free water decreased significantly. This may be due to the fact that with the addition of SPI, extracellular free water gradually transforms into bound water and non-flowable water. The water retention of meat products was mainly determined by the presence of non-flowable water between the muscle membranes. The more water was not easy to flow, the better the water retention of the product. Therefore, as the amount of SPI added increases, the water retention of the product gradually increases.

The effect of different starch additions on the T_2 relaxation time distribution of the product is shown in Figure 6. It can be seen from the figure that compared with the fresh meat, the relaxation time of the bound water and the non-flowable water of each experimental group were moved to a fast relaxation direction. so that the binding ability of these two parts of water to meat proteins was enhanced. And with the increase of starch addition, the combined water and the non-flowable water gradually turned to the left, indicated that the binding ability of water molecules and meat proteins was getting stronger and stronger. It can also be seen from the figure that compared with the fresh meat, the relaxation peak area of each part of the water in each experimental group was reduced, especially the relaxation peak area of the non-flowable water was most obvious.

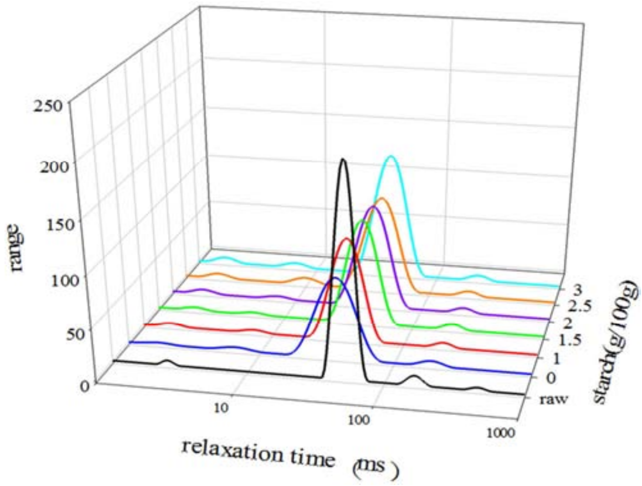

Figure 6. *Representative distributions of T_2 relaxation times for different starch addition.*

Table 3. *Influences of different starch level on T_2 relaxation times.*

Starch (g/100g)	T_{2b} (ms)	T_{21} (ms)	T_{22} (ms)
raw	2.77±0.21^{A}	51.40±2.2^{A}	173.33±35.77^{D}
0	1.90±0.12^{B}	40.83±4.77^{B}	189.67±43.51^{C}
1.0	1.83±0.06^{BC}	40.17±5.70^{B}	199.76±41.53^{BC}
1.5	1.80±0.10^{BCD}	39.63±1.32^{B}	206.67±73.51^{AB}
2.0	1.76±0.05^{BCD}	39.13±3.06^{BC}	210.21±59.98^{AB}
2.5	1.67±0.05^{CD}	37.40±5.96^{CD}	208.33±32.89^{AB}
3.0	1.63±0.05^{D}	36.53±3.86^{D}	216.67±65.77^{A}

Note: A-D in the same column of letters, the same difference is not significant ($P > 0.05$), the difference is significant ($P < 0.05$).

The effect of different starch additions on the T_2 relaxation time of the product was shown in Table 3. It can be seen from the table that different starch additions had a significant effect on the T_2 relaxation time of the product. Compared with fresh meat, the T_{2b} and T_{21} of each experimental group added with starch decreased, and the relaxation time of bound water and non-flowable water decreased significantly with the increase of starch addition. It showed that the relaxation time of combined water and non-flowable water were significantly shortened ($P < 0.05$), and the combination of these two water molecules with meat protein was getting closer and closer. This may be due to the oil emulsification of starch and the increased adhesion of meat products. With the increase of the amount of starch added, the emulsifying ability of the system was strengthened, and the water absorption capacity of the starch was gradually enhanced, so that the binding degree of the bound water and the non-flowing water with the meat protein was more and more tight, and the relaxation time becomes shorter.

Table 4. *Influences of different starch level on T_2 peak area fraction.*

Starch (g/100g)	A_{2b} (%)	A_{21} (%)	A_{22} (%)
raw	5.33±0.58^{CD}	204.02±1.58^{A}	9.33±1.15^{A}
0	4.67±0.57^{D}	80.33±1.53^{F}	6.00±0.58^{B}
1.0	5.65±0.58^{CD}	88.68±4.72^{E}	5.33±0.58^{BC}
1.5	6.66±0.58^{CD}	95.67±4.36^{E}	5.00±0.09^{BC}
2.0	7.33±0.58^{BC}	103.05±2.67^{D}	5.00±0.00^{BC}
2.5	9.03±0.58^{AB}	111.33±7.77^{C}	4.67±0.57^{BC}
3.0	11.06±0.87^{A}	122.33±2.08^{B}	3.89±0.51^{C}

Note: A-D in the same column of letters, the same difference is not significant (P > 0.05), the difference is significant (P < 0.05).

The effect of different starch additions on the percentage of the T_2 relaxation peak area of the product was shown in Table 4. It can be seen from the table that compared with fresh meat, the area of the easily-running water relaxation peak of each experimental group was significantly reduced (P < 0.05). This might be due to the salting of salt or other excipients, which increases the osmotic pressure inside the cells and affects the distribution of hydrogen ions. In addition, with the increase of starch addition, the peak area percentage of bound water and non-flowable water increased significantly (P < 0.05), and the peak area percentage of free water decreased significantly. This might be due to the strong water absorption of starch. As the amount of starch added increases, the water retention and water holding capacity of the product gradually increase, and the extracellular free water gradually transforms into bound water and non-flowable water [22].

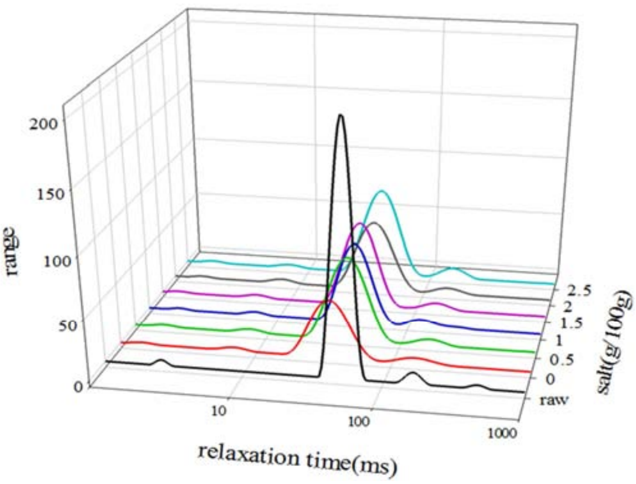

Figure 7. *Representative distributions of T_2 relaxation times for different salt addition.*

The change of T_2 relaxation time when different salt added was shown in Figure 7. It can be seen from the figure that compared with fresh meat, with the amount of salt added increases, the relaxation time of the combined water and the non-flowable water moved toward the fast relaxation direction. It showed that the relaxation time of these two parts of water became shorter, and the binding ability of these two parts of water with meat protein was enhanced (P < 0.05). At the same time, with the amount of salt added increasing, the relaxation time of combined water and non-flowable water gradually shifts to the left. It showed that the combination of these two parts of water whe muscle protein was getting stronger and stronger. It could also be seen from the figure that compared with fresh meat, the relaxation peak area of each state of water is significantly reduced, especially the area of the relaxation peak of the non-flowable water was most obvious.

Table 5. *Influences of different salt level on T_2 relaxation times.*

Salt (g/100g)	T_{2b} (ms)	T_{21} (ms)	T_{22} (ms)
raw	1.82±0.10^{A}	51.60±0.36^{A}	181.33±4.18^{A}
0	1.73±0.11^{B}	41.08±0.74^{B}	173.75±4.72^{AB}
0.5	1.73±0.09^{B}	39.31±0.39^{C}	172.67±4.76^{AB}
1.0	1.70±0.10^{B}	38.50±0.31^{C}	170.78±3.89^{ABC}
1.5	1.68±0.06^{B}	37.28±0.54^{D}	165.33±5.09^{BC}
2.0	1.63±0.07^{B}	36.47±0.15^{DE}	162.50±5.29^{BC}
2.5	1.60±0.05^{B}	35.35±0.68^{E}	158.35±5.05^{C}

Note: A-D in the same column of letters, the same difference is not significant (P > 0.05), the difference is significant (P < 0.05).

The effect of different salt addition on the T_2 relaxation time of the product is shown in Table 5. Compared with fresh meat, with the increase of salt addition, the three different states of water (T_{2b}, T_{21}, T_{22}) moved to the fast relaxation direction, that was, the relaxation time was shortened and the relaxation speed was increased. The T_{2b} relaxation time decreased from 1.73ms to 1.60ms, but the change was not significant (P > 0.05). This because that this part water was tightly bound to the protein in the meat. It was difficult to significantly affect with the salt addition. This is consistent with the findings of Wu Liangliang [23]; The T_{21} relaxation time decreased from 51.60ms to 35.35ms; the T_{22} relaxation time decreased from 173.75ms to 125.75ms. This indicated that with the increase of salt addition, the degree of binding strength between the non-flowable water and free water with the muscle protein molecules was significantly enhanced (P < 0.05), resulting in a significant decrease in the mobility of water molecules (P < 0.05), Thereby improving the water retention and yield of the product [24]. Compared with fresh meat, the relaxation time of T_{2b}, T_{21} and T_{22} in the experimental group with 0 g/100 g of salt addition were shortened, which might be related to other excipients added in the control group.

Table 6. *Influences of different salt level on T_2 peak area fraction.*

Salt (g/100g)	A_{2b} (%)	A_{21} (%)	A_{22} (%)
raw	5.25±0.52^{A}	201.25±8.50^{A}	9.50±0.58^{A}
0	1.87±0.15^{C}	65.75±1.71^{D}	9.35±0.24^{A}
0.5	1.90±0.08^{C}	67.00±1.41^{CD}	8.63±0.10^{B}
1.0	2.15±0.13^{BC}	68.75±0.96^{CD}	8.16±0.09^{BC}
1.5	2.31±0.16^{B}	70.50±1.29^{CD}	7.79±0.18^{CD}
2.0	2.48±0.17^{B}	71.54±1.29^{BC}	7.28±0.17^{D}
2.5	2.55±0.14^{B}	73.50±2.38^{B}	7.13±0.15^{D}

Note: A-D in the same column of letters, the same difference is not significant (P > 0.05), the difference is significant (P < 0.05).

The effect of different salt additions on the area percentage of T_2 relaxation peak was shown in Table 6. It can be seen from the table that compared with the fresh meat, the T_2 relaxation peak area of the three different state waters of each experimental group were significantly reduced ($P < 0.05$). This may be due to the fact that salt or other excipients addition affect the distribution of hydrogen protons in the meat; with the increase of salt addition, the peak area percentage of T_{2b} and T_{21} gradually increased ($P < 0.05$), while the percentage of T_{22} peak area was gradually decreased.

The ratio of relaxation peak area of bound water and free water was very small while the ratio of less-flowable water was largest This illustrated that with salt treatment, other moisture could converted into less-flowable water [25]. And when the salt addition amount was 2.5g/100g, the relaxation peak area of the bound water and the non-flowable water reaches the maximum and the relaxation peak area of the free water reaches the minimum, as well the water retention of the product was best [26].

3.4. Effect of Soy Protein Isolate, Starch and Salt on Color Difference

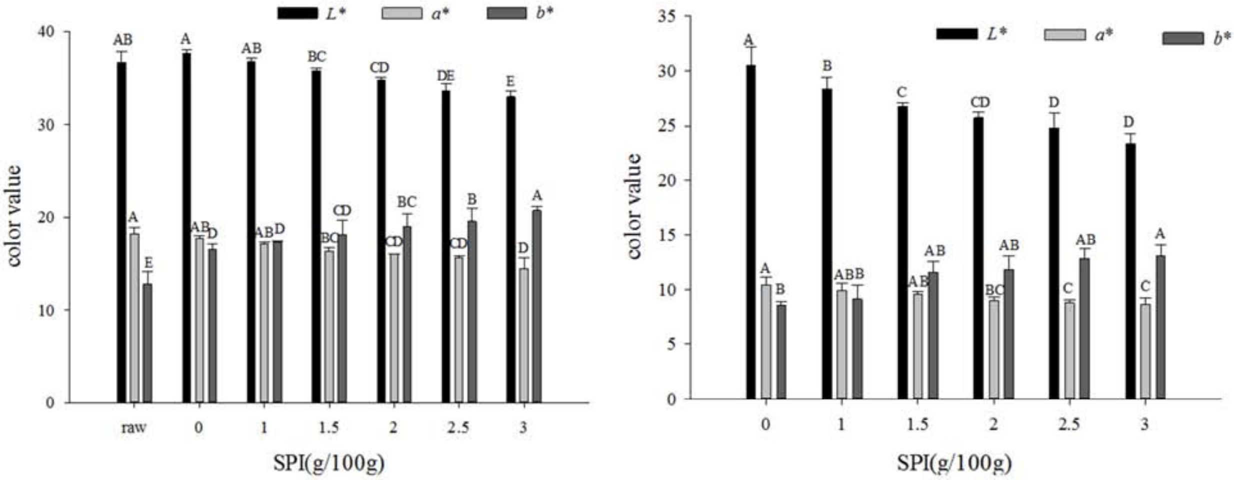

Figure 8. *Influences of different SPI addition on color.*

The effect of different SPI on product color difference was shown in Figure 8. For raw meat (left), the experimental group had lower *a** values and higher *b** values than fresh meat. This may be due to the fact that the addition of some excipients or binders cannot be completely absorbed by the product and adhere on the surface, the color of the product was affected. And with the increase of the SPI, the *L** value and redness value of the sample decreased significantly ($P < 0.05$), and the *b** value increased significantly ($P < 0.05$). This might be due to the fact that the SPI and water combined to form a mixture, With the increase of the amount of SPI added, SPI can not be completely absorbed by water and appear blocky, covering the surface of the minced meat with yellow streaks, affecting the color of the product [27].

For cooked meat (pictured right), as the amount of SPI added increases, the *L** value of the product decreased from about 30.3 when the amount was 0 g/100g to about 23.5 when the amount was 3.0 g/100g. The *a** value was reduced from about 10.6 when the amount was 0g/100g to about 8.6 when the amount was 3.0 g/100g. The *b** value increases from about 8.5 when the amount was 0 g/100 g to about 13.0 when the amount was 3.0 g/100 g. The *L** value and redness value of the product decreased significantly and the *b** value increased significantly ($P < 0.05$). This may be due to the fact that the soy protein isolate was denatured during the baking process, and the mixture formed with water solidifies to change the color of the product.

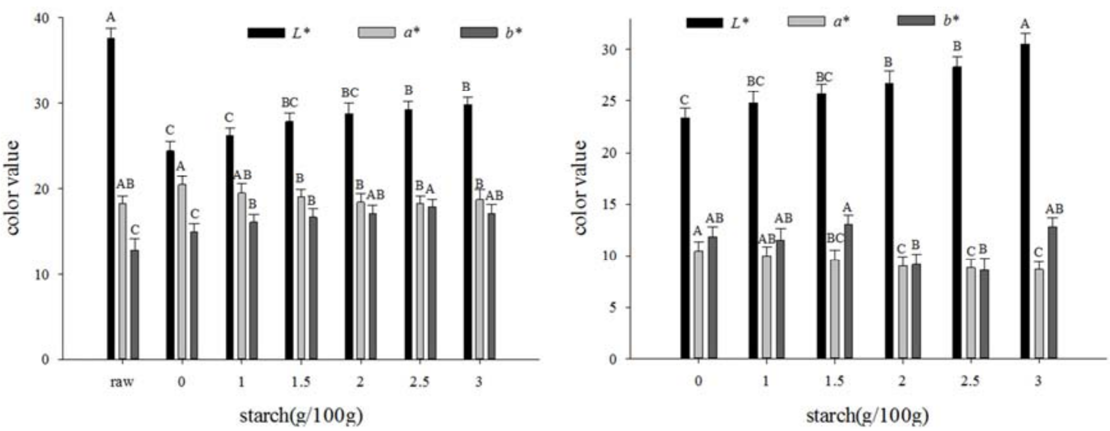

Figure 9. *Influences of different starch addition on color.*

The effect of different starch additions on product color difference was shown in Figure 9. For raw meat (left), the experimental group had lower *L** values and higher *b** values than fresh meat. This may be due to the fact that the addition of some excipients or binders cannot be completely absorbed by the meat product and adhere to the surface of the product, affecting the color of the product. At the same time, with the increase of starch addition, the *L** value of the sample gradually increased and the *a** value gradually decreased ($P < 0.05$). This may be due to the fact that the starch was soluble in water to form a transparent colloidal solution attached on

For cooked meat (right), with the amount of starch added increases, the *L** value of the product increases from about 23.3 when the amount was 0g/100g to about 28.5 when the amount was 3.0g/100g. The *a** value was reduced from about 11.6 when the amount was 0g/100 g to about 7.5 when the amount was 3.0 g/100 g. During the baking process, the *L** value of the product increased whlie the *a** value decreased significantly ($P < 0.05$). This may be due to the gradual swelling of the starch during the baking process, resulting in complete gelatinization of the starch. After gelatinization, the starch becomes a translucent colloidal solution with a certain viscosity and covers the surface of the meat piece, and gradually solidifies during heating to change the color of the product, which increases the *L** value [28].

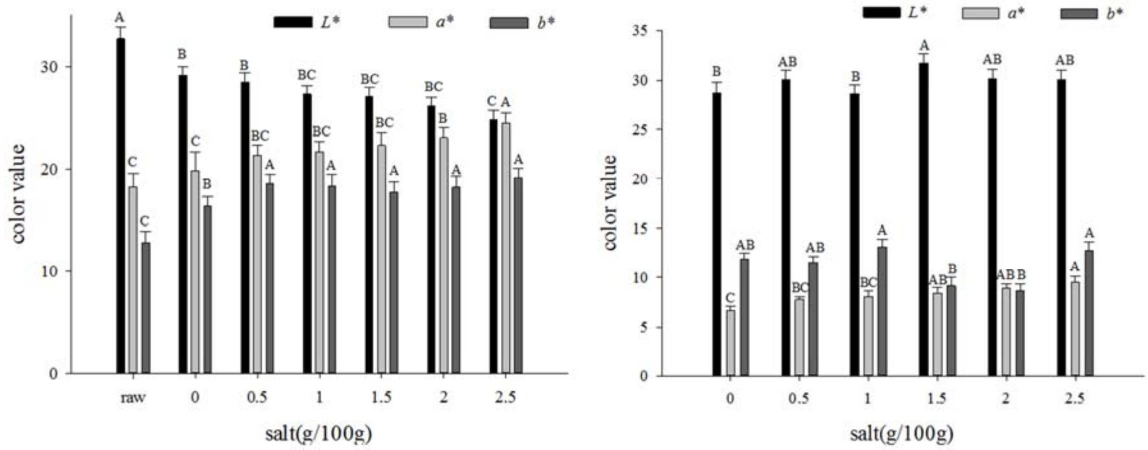

Figure 10. *Influences of different salt addition on color.*

The effect of different salt additions on product color difference was shown in Figure 10. The amount of different salt added has a significant effect on the color of the product. For raw meat (left), with the amount of salt added increases, the *L** value of the product decreases from about 29 when the amount is 0 g/100g to about 24 when the amount is 2.5 g/100g. The *a** value is increased from about 19 when the amount is 0 g/100 g to about 24 when the amount is 2.5 g/100 g. The *L** value of the product decreased while the *a** value increased ($P > 0.05$). This may be because the addition of salt can increase the water holding capacity of the meat product, and the water absorption capacity of the meat gel will affect the color of the meat product. The increase in moisture content reduces the oxygen content of the muscle gel, and the amount of hemoglobin surrounded by water molecules increases, eventually increasing the proportion of deoxymyoglobin in the meat gel system, making the meat gel The color is darkened and the redness is increased [29].

For cooked meat (pictured right), the *L** value did not change significantly with the increase of salt addition ($P > 0.05$). This might be due to the fact that the baking temperature and baking time used by each experimental group were consistent, so that the appearance of the meat product was invisible to the naked eye. The *a** value increased with the increase of salt addition, and the change was significant ($P < 0.05$). *b** was first lowered and then increased. This might be due to the fact that the three forms of myoglobin undergo a mutual transformation through oxidation and redox reaction during heating, which ultimately affects the surface color of the meat [30]. It can also be seen from Figure 10 that the change in *L** value, *a** value and *b** value was not significant ($P > 0.05$) when the salt addition amount was between 0.5 g/100 g and 1.5 g/100 g.

3.5. Effects of SPI, Starch and Salt on the Quality Characteristics

Table 7. *Influences of different SPI level on texture parameters.*

SPI (g/100g)	Hardness (g)	Spring	Chewing (g)	Cohesiveness
0	$1660.33{\pm}235.37^{D}$	$0.81{\pm}0.03^{E}$	$1571.83{\pm}209.04^{D}$	$0.73{\pm}0.05^{D}$
1.0	$1826.17{\pm}220.27^{D}$	$0.84{\pm}0.02^{DE}$	$1701.25{\pm}242.47^{CD}$	$0.77{\pm}0.13^{C}$
1.5	$2186.42{\pm}148.39^{CD}$	$0.87{\pm}0.03^{CD}$	$1934.98{\pm}186.26^{BC}$	$0.81{\pm}0.07^{BC}$
2.0	$2333.98{\pm}141.93^{BC}$	$0.90{\pm}0.02^{BC}$	$2276.67{\pm}195.59^{AB}$	$0.82{\pm}0.10^{BC}$
2.5	$2520.75{\pm}169.50^{A}$	$0.94{\pm}0.04^{AB}$	$2316.33{\pm}216.58^{A}$	$0.84{\pm}0.08^{B}$
3.0	$2773.30{\pm}235.59^{A}$	$0.96{\pm}0.03^{A}$	$2523.67{\pm}175.43^{A}$	$0.86{\pm}0.09^{A}$

Note: A-D in the same column of letters, the same difference is not significant ($P > 0.05$), the difference is significant ($P < 0.05$).

The effects of different SPI additions on the texture properties of the product were shown in Table 7. The addition of different SPI had a significant effect on the texture characteristics of the product (P<0.05). As the amount of SPI added increases, the texture properties of the product were significantly improved. This may be due to the gelation and foaming properties of SPI, which was obtained by heating, cooling, dialysis and alkali treatment of the dispersed substance of SPI. Moreover, the higher the protein content, the stronger and more elastic the hard gel was, and the foaming property of the SPI enables the protein molecules to reach the inner surface and rapidly spread, so that the texture properties of the product were improved.

Table 8. *Influences of different starch level on texture parameters.*

Starch (g/100g)	Hardness (g)	Spring	Chewing (g)	Cohesiveness
0	2211.65 ± 266.31^{D}	0.78 ± 0.02^{D}	1678.34 ± 277.06^{C}	0.68 ± 0.03^{C}
1.0	2431.62 ± 106.74^{CD}	0.80 ± 0.02^{CD}	1791.84 ± 128.57^{BC}	0.71 ± 0.02^{BC}
1.5	2831.02 ± 160.15^{BC}	0.83 ± 0.02^{BCD}	1812.31 ± 113.21^{BC}	0.74 ± 0.05^{BC}
2.0	2936.86 ± 224.69^{BC}	0.84 ± 0.03^{BC}	1863.34 ± 98.59^{BC}	0.77 ± 0.02^{B}
2.5	3231.31 ± 247.75^{AB}	0.87 ± 0.03^{AB}	1995.43 ± 110.34^{AB}	0.81 ± 0.02^{A}
3.0	3594.63 ± 152.51^{A}	0.90 ± 0.05^{A}	2232.63 ± 114.94^{A}	0.84 ± 0.05^{A}

Note: A-D in the same column of letters, the same difference is not significant (P > 0.05), the difference is significant (P < 0.05).

The effect of different starch additions on the texture properties of the product was shown in Table 8. It can be seen from the table that different starch additions had a significant effect on the texture characteristics of the product (P < 0.05). As the amount of starch added increases, the hardness and elasticity values of the product were increased, and the texture properties of the product were significantly improved. This may be due to the water absorption, swelling, and gelatinization of the starch granules during heating. Since the gelatinization temperature of the starch granules was higher than the denaturation temperature of the muscle protein, So, when the starch was gelatinized, various proteins in the muscle had reached the denatured solidification bonding temperature and gradually formed a three-dimensional network structure. At this time, since the colloid formed by starch gelatinization was fixed in the mesh (mesh gap), the mixed sol can combine with the residual moisture inside and outside the muscle reticular structure to form a larger and more complicated colloid. Therefore, the inherent moisture in the muscle was fixe, and it was not easily lost during the subsequent heat treatment, thereby improving the water holding capacity and adhesion of the meat product. The muscle tissue was bonded and filled with holes to make the finished product beautiful and present a good tissue morphology [31].

Table 9. *Influences of different salt level on texture parameters.*

Salt (g/100g)	Hardness (g)	Spring	Chewing (g)	Cohesiveness
0	2050.33 ± 135.37^{D}	0.76 ± 0.03^{D}	1171.83 ± 129.04^{D}	0.78 ± 0.05^{D}
0.5	2216.17 ± 120.27^{D}	0.77 ± 0.02^{D}	1201.25 ± 122.47^{CD}	0.82 ± 0.13^{C}
1.0	2476.42 ± 148.39^{C}	0.82 ± 0.03^{C}	1434.98 ± 136.26^{BC}	0.86 ± 0.07^{BC}
1.5	2743.98 ± 141.93^{BC}	0.85 ± 0.02^{BC}	1676.67 ± 135.59^{AB}	0.87 ± 0.10^{BC}
2.0	2910.75 ± 169.50^{A}	0.89 ± 0.04^{AB}	1816.33 ± 126.58^{A}	0.89 ± 0.08^{B}
2.5	3063.30 ± 185.59^{A}	0.91 ± 0.03^{A}	1923.67 ± 125.43^{A}	0.92 ± 0.09^{A}

Note: A-D in the same column of letters, the same difference is not significant (P > 0.05), the difference is significant (P < 0.05).

The effect of different salt addition on the texture characteristics of the product was shown in Table 9. Different amounts of salt added had a significant impact on the texture characteristics of the product. As the amount of salt added increases, the hardness and elasticity values of the product were increased significantly, and the texture properties of the product were improved. This might be due to the fact that salt can act on the meat protein system, thereby the amount of myofibrillar protein eluted were increased, the cross-linking between protein polypeptide chains were promoted, and the interaction between proteins was enhanced, a stable three-dimensional network structure was formed. Thereby, it played the role of improved the texture characteristics such as hardness and chewiness of the product.

3.6. Effect of SPI, Starch and Salt on Sensory Evaluations

Table 10. *Influences of different SPI level on sensory evaluation.*

SPI (g/100g)	Color	odor	tissue state	taste	overall acceptance
0	5.81 ± 0.33^{B}	6.53 ± 0.52^{A}	5.61 ± 0.34^{C}	6.32 ± 0.54^{C}	6.62 ± 0.43^{B}
1.0	6.91 ± 0.23^{A}	6.84 ± 0.31^{A}	6.63 ± 0.30^{BC}	6.52 ± 0.31^{BC}	7.02 ± 0.21^{AB}
1.5	7.01 ± 0.22^{A}	6.74 ± 0.62^{A}	7.01 ± 0.24^{AB}	7.23 ± 0.31^{AB}	7.13 ± 0.31^{AB}
2.0	7.02 ± 0.23^{A}	7.01 ± 0.34^{A}	7.42 ± 0.42^{A}	7.53 ± 0.34^{A}	7.61 ± 0.43^{A}
2.5	7.03 ± 0.24^{A}	6.73 ± 0.31^{A}	6.93 ± 0.34^{BC}	6.72 ± 0.23^{ABC}	6.7 ± 0.51^{B}
3.0	7.02 ± 0.34^{A}	6.74 ± 0.43^{A}	6.44 ± 0.76^{BC}	6.55 ± 0.32^{BC}	6.53 ± 0.30^{B}

Note: A-C in the same column of letters, the same difference is not significant (P > 0.05), the difference is significant (P < 0.05).

The effects of different SPI additions on sensory evaluation of the product were shown in Table 10. It can be seen from the table that, compared with the control group, with the increase of the amount of SPI added, the color of the product was brighter, the taste was better, and as well the tableting property. And when the amount of SPI added was 2.0 g/100g, the sensory indexes were best and the overall acceptability was highest; Continue to add soy protein isolate, the color was slightly dark, the product was slightly bean flavor, Yellow streaks appeared between the meat pieces, and the taste was awkward, and the sensory indexes showed a downward trend (P < 0.05). This might be due to the fact that the continued addition of SPI, the water retention of the product was further increased, the tenderness of the meat product was continued to rise, resulting in a soft tissue state, the chewiness was decreased and the mouth feels awkward, and the taste of the beans appears. Therefore, it was finally determined that the optimum addition amount of soy protein isolate was 2.0 g/100 g.

Table 11. *Influences of different starch level on sensory evaluation.*

Starch (g/100g)	Color	odor	tissue state	taste	overall acceptance
0	$5.81±0.33^{AB}$	$6.53±0.52^{A}$	$5.61±0.34^{C}$	$6.42±0.54^{C}$	$6.56±0.43^{B}$
1.0	$7.02±0.23^{A}$	$6.84±0.31^{A}$	$6.63±0.30^{BC}$	$6.52±0.32^{BC}$	$7.02±0.21^{AB}$
1.5	$7.21±0.22^{A}$	$6.94±0.62^{A}$	$7.42±0.24^{AB}$	$7.83±0.31^{AB}$	$7.13±0.31^{AB}$
2.0	$7.02±0.23^{A}$	$7.01±0.34^{A}$	$7.01±0.42^{A}$	$7.53±0.34^{A}$	$7.10±0.43^{A}$
2.5	$7.03±0.24^{A}$	$6.53±0.31^{A}$	$6.93±0.34^{BC}$	$6.72±0.23^{ABC}$	$6.24±0.51^{B}$
3.0	$6.84±0.34^{A}$	$6.74±0.43^{A}$	$6.44±0.76^{BC}$	$6.55±0.32^{BC}$	$6.53±0.30^{B}$

Note: A-C in the same column of letters, the same difference is not significant (P > 0.05), the difference is significant (P < 0.05).

The effect of different starch additions on the sensory evaluation of the product was shown in Table 11. It can be seen from the table that, compared with the control group, with the increase of the amount of starch, the color of the product was brighter, the taste was better, and as well the tableting property. And when the starch addition amount was 2.0 g/100g, the sensory indexes were best and the overall acceptability was highest; Continue to add starch, white streaks appeared between the meat pieces, the mouth felt awkward, and the sensory indicators showed a downward trend (P < 0.05). This might be due to excessive starch, which makes the product rough, hard, inelastic, light in color and poor in taste. Therefore, in the production should pay attention to control the amount of starch to ensure product quality. The quality characteristics and sensory indicators of the integrated product finally determined that the optimal addition amount of starch in the production was 2.0 g/100 g.

Table 12. *Influences of different salt level on sensory evaluation.*

Salt (g/100g)	Color	odor	tissue state	taste	overall acceptance
0	$6.63±0.38^{B}$	$6.37±015^{C}$	$6.07±0.14^{C}$	$5.13±0.15^{D}$	$5.10±0.26^{C}$
0.5	$6.83±0.35^{B}$	$6.70±0.10^{BC}$	$6.27±0.20^{BC}$	$5.73±0.16^{C}$	$5.63±0.21^{C}$
1.0	$7.10±0.26^{AB}$	$7.07±0.15^{AB}$	$6.47±0.15^{BC}$	$6.30±0.26^{BC}$	$6.37±0.15^{B}$
1.5	$7.60±0.20^{A}$	$7.43±0.40^{A}$	$7.21±0.21^{A}$	$7.53±0.26^{A}$	$7.23±0.21^{A}$
2.0	$7.23±0.11^{AB}$	$7.33±0.20^{A}$	$6.60±0.17^{B}$	$6.80±0.22^{B}$	$6.91±0.12^{AB}$
2.5	$7.01±0.21^{AB}$	$7.13±0.21^{AB}$	$6.53±0.16^{BC}$	$6.27±0.23^{BC}$	$6.57±0.21^{B}$

Note: A-C in the same column of letters, the same difference is not significant (P > 0.05), the difference is significant (P < 0.05).

The effect of different salt additions on the sensory evaluation of the products was shown in Table 12. The amount of salt added had a significant effect on the sensory quality of beef products (P < 0.05). When the amount of salt added is 0%, the color was dark, the saltiness was insufficient, and the mouth feels awkward. This was because the meat samples contains a lot of odorous ingredients such as protein and fat, which often need to be expressed on a certain salty taste [32]. At this time, the meat sample was brittle during the baking process, and the formability was not good and it was difficult to be accepted; As the amount of salt added increased, the sensory scores increasing, and the quality of the meat was getting better and better. When the amount of salt added was 1.5 g/100g, the quality of the meat was best, the color was bright reddish brown, the meat was prominent, the salty taste was moderate, the meat pieces were not brittle during the baking process, and the formability was good. The highest sensory evaluation vales, Continue to increase the amount of salt, the color was darker, the taste was too salty, the meat flavor was covered by salt, and the sensory scores begin to decline. This may be due to the continued addition of salt, the water retention of the product was further increased, resulting in a soft tissue state, a decrease in chewiness and a salty taste. This indicated that the addition of salt had a significant impact on product quality characteristics and sensory quality. Based on the various sensory indicators and overall acceptability, the optimal addition of salt was determined to be 1.5 g/100g.

4. Discussion

4.1. Mechanism of the Effect of SPI on the Quality Characteristics

SPI was a high-purity soy protein product obtained from defatted soybean meal. Its protein content (on a dry basis) was over 90%, which was the highest protein content of soybean products. SPI also has very good features. Experiments have shown that, except for SPI, which has gelatinity, the other soy protein products were basically not gelatinous. In the processing of meat products, it could retain or emulsify the fat in the meat products, combined with moisture, And improve the organization, so that the internal structure of the meat products was fine, the bonding was good and flexible, and the slicing was good, the surface of the product was smooth and delicate, and the tenderness was improved; at the same time the fat was emulsified, improve the water retention and yield of meat products were improved.

This experiment explores the effect of adding SPI on product quality and sensory properties. The results showed that with the increase of SPI addition, the yield and bond strength of the product increased gradually ($P < 0.05$). The thawing loss and water activity decreased gradually ($P < 0.05$), and the texture characteristics of the product were improved ($P < 0.05$). This was because SPI has strong water absorption and gelation. The interaction between the active group and the muscle protein forms a more stable gel network structure, which increases the viscosity of the product. At the same time, more water was retained to enhance the water retention of the product. This was similar to the research results of Ma Yuxiang et al. [33]. Ma Yuxiang added a certain amount of soy protein isolate to the ham and measured the yield. It was found that the addition of SPI can significantly increased the yield of ham sausage. At the same time, it increased the water holding capacity and oil holding capacity of the ham.

4.2. Mechanism of the Effect of Starch on the Quality Characteristics

As a food additive, starch had the functions of enhancing gel strength, improving tissue structure, enhancing water retention, improving yield, and reducing production costs. At the same time, the addition of starch can prevent the oil product from seeping, and the product had a sticky and smooth tongue feeling, thereby improving product quality. Therefore, starch was widely used in meat products. However, different starch types have different effects on meat products. The adhesion and hardness of the meat emulsion increase with increasing viscosity and water retention, and also with the increase of amylopectin. Potato starch with high amylopectin produces much higher gel binding and elasticity than wheat starch with high amylose content. And the tensile strength of the gel also increases with the increase of amylopectin. Therefore, in this experiment, potato starch containing more amylopectin was selected. It is important to explore the effects of different potato starch additions on the properties of the conditioned recombinant beef products.

The results showed that with the increase of starch addition, the yield and bond strength of the product increased significantly ($P < 0.05$), the thawing loss and water activity decreased significantly ($P < 0.05$), and the texture properties of the product were improved. $P < 0.05$), Just because starch has a gelatinized nature, During the baking process of the product, the starch granules swell, and the gelatinization of the starch occurs. After gelatinization, the starch formed a transparent colloid that was fixed in the mesh and combines with the remaining moisture in the muscle network structure to become a more powerful colloid. And the bond strength and texture properties of the product were improved, this more powerful colloid can fixed the water molecules inside the muscle, which improved the water retention of the product. However, the amount of starch added should not be too high, too much starch will make the product texture rough, hard, inelastic, light color, poor mouthfeel, So, in order to ensure the quality of the product in the production process, the amount of starch added should be controlled.

4.3. Mechanism of the Effect of Salt on the Quality Characteristics

The initial application of salt in meat products was preservative flavoring. The addition of salt to fresh meat had the effect of increasing palatability and was added to the cured meat to provide antiseptic. With the research on the processing technology of meat products, the researchers found that there was a significant interaction between salt and phosphate. The main manifestation was that salt can promote the full play of phosphate in the system. In addition, salt was also an important extractant of salt-soluble myofibrillar protein in muscle. As the concentration of the added salt increases, the gel performance was inevitably increased, thereby obtaining a product having a good texture. However, when the concentration of salt added has a certain saturation effect on the extraction of functional protein, that is, after reaching a certain ionic strength, the increase of salt concentration no longer brings about a significant increase in the amount of muscle protein dissolved, but remains in a relatively stable state.

The results showed that with the increase of salt addition, the yield and bond strength of the product increased gradually ($P < 0.05$), the thawing loss and water activity decreased gradually ($P < 0.05$), and the texture properties of the product were improved. $P < 0.05$), It was because myofibrillar protein was salt-soluble, and as the amount of salt added increases, the concentration of extractable myofibrillar protein increased. The extracted "fibrin" of myofibrillar protein and water form a sticky "exudate" attached to the surface of the meat piece, which can increase the viscosity. Since salt could act on the protein system of meat products, thereby the amount of dissolution of myofibrillar proteins could be increased, the cross-linking between protein polypeptide chains could be promoted, and the interaction between proteins to form a stable three-dimensional network structure was enhanced. At the same time, the binding force to moisture is enhanced, and the texture properties and water retention of the product are improved [34].

5. Conclusion

With the increase of the amount of soy protein isolate, the yield and bond strength of the product increased gradually ($P < 0.05$), the thawing loss and water activity decreased gradually ($P < 0.05$), and the texture properties of the product were improved. ($P < 0.05$), the brightness value and redness value of raw meat and cooked meat gradually decreased. In addition, as the amount of soy protein isolate added increases, both T_{2b} and T_{21} of the product move toward a faster relaxation direction. When the amount of soy protein isolate added was 2.0 g/100g, the sensory scores of the products reach the highest. Therefore, it is finally determined that in the production process of the ready-to-eat restructured beef products, the optimal addition amount of soy protein isolate should not exceed 2.0 g/100 g;

With the increase of starch addition, the product yield and bond strength increased significantly ($P < 0.05$), the thawing loss and water activity decreased significantly ($P < 0.05$), and the texture properties of the product were improved ($P < 0.05$), the brightness value of the raw meat and cooked meat gradually increased and the redness value gradually decreased ($P < 0.05$). In addition, as the amount of starch added increases, the T_{2b} and T_{21} of the product gradually move toward a faster relaxation direction. And when the starch addition amount was 2.0 g/100g, the sensory score of the product reaches the highest, so in the production process of the ready-to-eat restructured beef products, the added amount of starch should not exceed 2.0 g/100g;

With the increase of salt addition, the product yield and bond strength increased gradually ($P < 0.05$), the thawing loss and water activity decreased gradually ($P < 0.05$), and the texture properties of the product were improved ($P < 0.05$), the brightness value of raw meat and cooked meat increased and the redness value decreased ($P < 0.05$). In addition, as the amount of salt added increases, the T_{2b} and T_{21} of the product gradually move toward a faster relaxation direction. When the amount of salt added was 1.5 g/100g, the sensory scores of the products were highest. Therefore, it was finally determined that in the production process of the ready-to-eat restructured beef products, the optimal addition amount of salt is 1.5 g/100g.

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