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Development and Effect Verification of Beef Cattle Carcass Grading Camera Equipment System

He Zhu[1], Xinyuan Wang[1], Tianxue Sun[1], Chenhao He[2], Li Zhang[3], Tao Ma[3], Dong Chen[4]

[1]Shandong Agriculture and Engineering University; China
[2]Shandong Aohang and Niu Pastoral Industry Co., Ltd;, China
[3]Shangdu Hengchang Co., Ltd, China
[4]Hunan Tianhua Industrial Co., Ltd, China

Abstract: This paper first discusses the development status of beef cattle carcass grading and photographic equipment at home and abroad, then carries out the equipment design and model establishment, and finally conducts sensory carcass assessment and grading and environmental simulation detection experiments through experiments, and uses the colorimeter and beef carcass intelligent grading system to detect the color difference L*, a*, b* values of meat samples in different environments, color space RGB and HSV color parameters, compare the influence of different environments on meat color parameters and grading results, and verify the feasibility of beef carcass grading photography equipment. The results show that the overall values of the equipment group are at a stable level and in line with the sensory evaluation, so the beef carcass grading camera equipment can effectively avoid the influence of external objective factors, such as: light and dark, poor light source, limiter and framing distance. At the same time, it reduces the interference of operators in the classification process and other problems such as the subjective negligence of the operator on the classification results. The project design equipment structure is simple and reliable, automation equipment is easy to operate and low cost, the new beef cattle carcass grading photographic equipment, suitable for promotion and mass production into the market, can improve labor production efficiency, promote the development of local enterprises' meat industry, increase enterprise income, reduce the production cost of enterprises, to promote the standardization and unification of beef cattle industry grading system.

Keywords: Beef, Snowflake beef grading, Snowflake beef grading camera equipment.

1. Foreword

1.1. Background

With the rapid development of China's economy and the continuous improvement of residents' living standards, the dietary structure of Chinese residents is constantly updated and improved, and the demand for beef is also increasing year by year, especially the high-quality beef cattle carcass with the advantages of high protein, low fat, rich in vitamins and mineral elements. At present, there are many quality factors that affect the value of meat, such as: beef cattle breed, age and feeding; meat color, texture and fat distribution; the content and proportion of various amino acids.[1] But the main factors are beef cattle carcass weight, meat production, etc. The grading of beef cattle carcass quality mainly depends on two key factors: beef cattle carcass yield and meat quality. Among them, meat quality is the key factor that determines the market price of beef cattle carcass. The classification of beef cattle carcasses according to meat quality can promote the production of high-quality beef cattle carcasses in China, improve the profit level of farmers' breeding, and meet the domestic market demand for high-quality beef cattle carcasses.

However, at present, the classification of meat quality of beef cattle carcass in China basically relies on sensory evaluation methods, and there are many chaotic situations in the status quo of meat quality classification, such as:

(1) The grading differences between individual enterprise standards and private standards lead to confusion in the pricing of high-quality high-grade beef cattle carcasses in the market;

(2) The collection and evaluation procedures of testing indicators in the existing industry standards are slightly complicated, resulting in the inability of enterprise graders to operate proficiently;

(3) The overly simple meat quality grading standard cannot be effectively and objectively evaluated, which has caused the meat grading mark in the market to seriously imitate Japan and Australia, and the market mark is disorderly and chaotic, which cannot guarantee the quality of beef cattle carcass.

Therefore, the development of a beef cattle carcass meat quality grading procedure with unified detection indicators, concise operating procedures and objective evaluation procedures is the key factor to solve the above problems.

Compared with the traditional sensory evaluation method, an intelligent grading photo identification equipment system can play an effective role in standardizing the determination of beef cattle carcass, solve the existing main problems, meet the needs of the industry, and promote the development of beef cattle carcass grading industry.

1.2. The purpose and significance of the study

In order to meet the requirements of objective, standardized and efficient meat classification of beef cattle carcass, the research and development of "beef cattle carcass grading and photographic equipment" takes visual recognition and positioning technology, picture automatic photo capture technology, and white LED supplemental light photography technology as the core, so as to avoid the interference of undesirable factors when taking pictures and identifying, and solve the current problems such as being easily disturbed by surrounding light and not easy to operate. The grading process is more accurate and efficient, the evaluation results are more authoritative, and the evaluation results are more objective, authentic and reliable.

At present, there is no unified classification system for beef cattle carcass in China. Under the premise that Shandong Province has a high advantage in high-end beef cattle breeding, if it takes the lead in the research and development and application of the objective classification system of high-grade beef cattle, it can quickly form a technical application advantage, which can not only solve the problem of the lack of a unified objective classification system for beef cattle carcass in China, but also seize the technological opportunity and lead the development of the domestic high-end beef cattle industry.

1.3. Development status

1.3.1. Research status of beef cattle carcass grading and photographing equipment

At present, the model of the camera equipment that has been mass-produced and applied in the United States is the product VGB2000 of E+V Technology, as shown in Figure 1. However, the equipment is a wired device, which needs to be used in a specific acid discharge room for taking pictures, and the equipment is large in size, heavy and difficult to operate.

Figure 1. Picture of American beef grading equipment

Shen Mingxia et al. invented the "Portable Beef Quality Grading System Image Acquisition Device Based on Embedded Machine Vision Technology", which borrowed from VGB2000 American products, but also because of the problem of excessive size, it is not conducive to hand-held carrying operation and signal transmission.

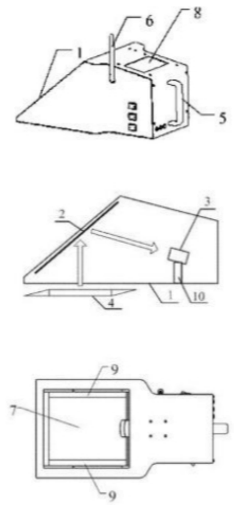


Figure 2. Patent diagram of image acquisition device for domestic beef quality classification system

In addition, during the research process, the interference of the surrounding light source can seriously affect the data analysis results. To this end, Peng Zengqi et al. studied putting cattle carcasses into a camera obsca for detection, but this method has a large demand for space and is not conducive to actual operation in the factory.

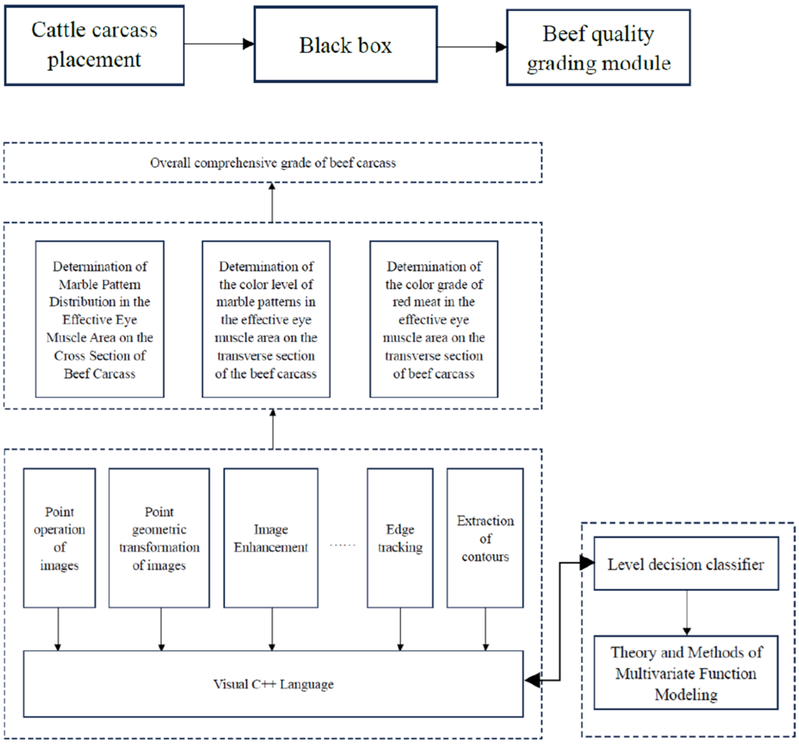


Figure 3. Schematic diagram of beef carcass dark box operation in domestic beef quality grading system

It can be seen that the design, development and innovation of beef cattle carcass grading and photography equipment have always been the internal equipment of the beef industry However, the development trend of such equipment is relatively slow, and it is limited by the large size, heavy weight, susceptibility to external environmental interference, and limited scope of application, and there is still no major breakthrough.

1.3.2. Research status of visual processing technology

In 1995, T.L Gardner, H.G., and D.M. Allen et al. used an RGB color camera to collect images of eye muscles and count the area and distribution of fat in the muscles, indicating that computer image processing technology can be used to determine the quality grade of beef. Subsequently, Jeyamkondan et al[2], successfully used a computer to predict beef tenderness, converted the RGB image of beef into a CIE L*a*b* image, and then analyzed it into three components: L*, a*, and b* for grade prediction, and the results showed that the accuracy of the prediction image was 92%.

In 2006, Fang Ming et al. designed a meat color and fat color rating algorithm based on the minimum distance of L*a*b* color difference for the first computer vision inspection of beef carcass quality grade in China, with a total accuracy rate of 93.75% and 92.5%, respectively. In 2023, Pannier et al[3], described a grading study of beef carcasses in the wide visual marbling score range of the Marel conveyor belt vision scanner for predicting chemical muscle fat(IMF%), Australian Meat Standards (MSA) and the ability of some steaks to score marble. The methodology shows precise and accurate IMF% projections.

It can be seen that this topic has always been a research hotspot in foreign countries to break through the classification and evaluation of beef cattle carcass. According to the above party.

It can be seen that the RGB color mode and CIE L*a*b* color space based on simple, stable and fast algorithms can better adapt to the needs of online detection, but the segmentation effect needs to be improved in complex environments such as uneven lighting[4]. Therefore, on the basis of the reasonable selection of the color space mode of the detection method, it is an important direction for the future research on beef cattle carcass classification to realize the optimization and improvement of equipment and reduce the interference of the surrounding environment.

2. Experimental Materials

2.1. Experimental instruments

Table 1. Main Instruments and Equipment

Instrument	Model	Factory
Colorimeter	WR-10QC type	Shenzhen Weifu Optoelectronics Technology Co., Ltd
Graded camera equipment	Handheld	Hengrun Machinery Manufacturing Co., Ltd
Flashlight	Model 328-10W	Oaks Electric Co., Ltd
Black blackout cloth	2m×2m type	Shaoxing Salted Fish Textile Co., Ltd
Limiter	5cm×5cm type	Hengrun Machinery Manufacturing Co., Ltd
White acrylic sheet	30cm×30cm type	Qingqing Chengxin Acrylic Processing Co., Ltd
Black acrylic sheet	30cm×30cm type	Qingqing Chengxin Acrylic Processing Co., Ltd
Scale	20cm type	Deli Stationery Co., Ltd

2.2. Experimental raw materials

The beef used in the experiment was a fresh, high-quality beef carcass section.

3. Experimental Methods

3.1. Design and model establishment of beef cattle carcass grading and photographic equipment

In the early stage of the design of this equipment, the current situation of the product is investigated, combined with the domestic and foreign conditions and the research situation of the enterprise.

In view of the existing photographic equipment, which is susceptible to the problems of inconsistent photographic positioning, interference of surrounding light, large footprint, which is not conducive to operation and data transmission relying on data cables, the innovative design of "beef cattle carcass grading photographic equipment" takes visual recognition automatic positioning technology, picture automatic photographic capture technology, white LED supplemental light photographic technology as the core technological innovation breakthrough direction, and integrates the joint control system of automation equipment as the core to solve many problems currently faced, and formulates a feasible design scheme for photographic equipment. Integrated visual recognition and positioning technology, picture automatic photo capture technology, white LED supplementary light photography technology, wireless upload technology, etc., can form a unified photo positioning, simple and reliable structure, high degree of joint control of automation equipment, low equipment cost, not easy to be disturbed by the surrounding light of the new beef cattle carcass grading photography equipment, easy to promote and mass production into the market, promote the development of local enterprises in the meat industry, and promote the standardization of the industry's grading system.

According to the overall scheme, combined with the mutual cooperation between the systems, the beef cattle carcass grading photo terminal is designed the mechanical structure of the device. The device is a hollow rectangular frame, and the entire bottom surface is intercepted, compared with the original rectangular bottom surface, the trapezoidal section can increase the image framing area and fix the image acquisition range. The bottom edge of the equipment frame is hemmed to improve the safety of the equipment while playing a fixed role. The top surface of the device is reserved for a groove position, which is convenient for fixing image acquisition equipment such as cameras or mobile phones during operation. The top surface of the device is reserved with a rectangular square hole, which is conducive to the framing of the camera and the entry of the fill light source, which can avoid the inside of the frame from being too dim during image acquisition, reduce the influence of external bad light sources and make color information such as flesh color more accurate. A distance sensor is installed at the rear of the equipment frame to ensure that the image acquisition distance is fixed and to avoid distance problems.

The size of the captured images is inconsistent. At the same time, the outer skeleton shell of the equipment is welded made of stainless steel, which meets the requirements of strong closure, light, hygiene, easy cleaning and light weight, so as to adapt to the different scenes when taking pictures of beef cattle carcass grading, and can be applied to many occasions and has strong generalizability.

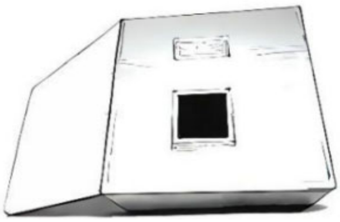


Figure 4. Design sketch of beef carcass grading photography equipment

The equipment can flexibly respond to different beef cattle carcass grading occasions, positioning mechanism and distance sensor equipment. It can control the fixed image acquisition area and distance, and the LED fill light helps the normal display of flesh color, avoids the influence of external adverse environmental light sources, and improves the objectivity, authenticity and accuracy of the evaluation results. The design scheme of this equipment not only avoids the influence of external adverse environmental factors on image acquisition, but also greatly alleviates the differences caused by subjective factors of graders, such as the uncontrollable and fixed framing distance, and the different areas of the acquisition range.

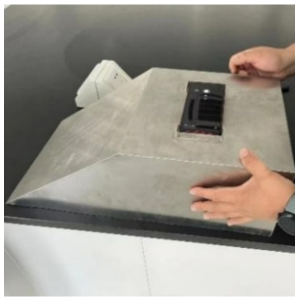


Figure 5. Effect of simulation operation of beef carcass grading camera equipment

3.2. Design of Experiments

By reviewing the literature, it can be seen that the current classification of carcasses is still mainly sensory, and research experiments show that it is calculated RGB, HSV and CIE L*a*b* color space can effectively improve the accuracy of the results in the detection of beef carcass, so the three groups of RGB, HSV and CIE L*a*b* color spaces were selected as the detection method as the basis for this experiment, and the carcass sensory evaluation and grading results were used as the control reference.

In order to verify the feasibility of the grading and photographing equipment for beef cattle carcass, the carcass was first comprehensively evaluated by sensory evaluation.

The grading test was carried out according to the carcass grading standards at home and abroad, and the grading results of the sensory group were used as the follow-up experimental data control. Then, the environmental simulation test experiment was carried out to test whether the grading camera equipment could resist the interference of the external adverse environment, and assist the grading operation to improve the accuracy of the results. The environmental simulation detection experiment was divided into two groups with and without equipment to carry out the detection experiment, each group used a colorimeter and a beef cattle carcass intelligent grading detection system to analyze the color parameters of L*a*b*, RGB and HSV, and compared the influence of different environments on meat color parameters and grading results according to the values of the three parameters. A comparative analysis of the actual situation of the carcass sensory rating parameters in the environmental simulation test experiment and the carcass sensory rating parameters will obtain ANOVA data analysis was performed on the outcome parameters.

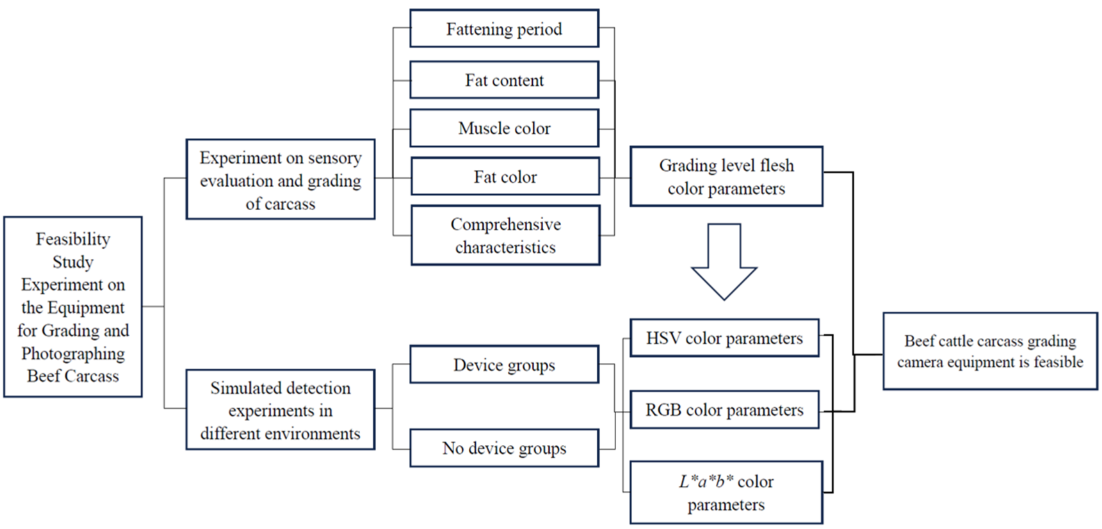


Figure 6. Experimental flowchart

3.3. Experimental principle

3.3.1. The principle of comprehensive evaluation of carcass sensory assessment

The high, medium, and low grades of beef cattle, i.e., A, B, and C, are usually judged by the length of the fattening period of beef cattle. After slaughter, the carcass of beef cattle is deacidified for more than 72 hours, and the carcass of beef cattle is dissected between the sixth and seventh ribs, and the grade is based on the fat content and color of the cut surface, and the color and texture of the muscle. According to the comprehensive quality grading and meat quality grade of beef cattle carcass, the comprehensive grade of beef cattle carcasses is evaluated. At present, carcass grading in China is still dominated by sensory grading, which is mainly divided into fattening stage grading, fat content grading, muscle color grading, and fat color grading and evaluation of meat elasticity characteristics in five aspects. Refer to the Japanese carcass grading requirements and the general current beef cattle carcass grading standards, and use the reference color card drawing board as a comparison to conduct rating analysis.

3.3.2. HSV color space principle

HSV consists of Hue (Hue), which represents the dominant color of the spectrum, which is represented by an angle of 0 degrees to 360 degrees, Saturation (Saturation), which represents the richness of the color, and V(Value)[5], which represents the brightness of the spectrum. The HSV model is a nonlinear, perception-oriented model. It has the advantage of being closer to the human visual perception of color. It can divide basic color characteristics into three separate components: lightness, hue, and saturation. Using the HSV model, starting from the basic color features and using the chromaticity components for cluster analysis, the influence of lighting changes can be effectively overcome.

Hue H refers to the information about the color there, i.e., the position of the color in the spectrum. The color space is measured in angles, ranging from 0° to 360°, and is usually measured in terms of angles.

Saturation S: The value range is 0.0-1.0, and the saturation defines the composition of the color in the color space, the higher the saturation, the darker the color, and the lower the saturation, the lighter the color.

Luminosity V: The value range is 0.0-1.0. A V value of 0 is black, and a V value of 1 is white. The luminosity value V provides a visual reflection of how light or dark a color space is.

3.3.3. RGB color space principle

The RGB color space is mainly composed of three basic color information: R (Red), G (Green), and B (Blue) are the basic components.[6] The three primary colors are applied and combined in different ways, resulting in different colors. It is commonly known as the trichromatic pattern. The value range of each element in the RGB color space is 0-256. RGB color values refer to the relative brightness of the three primary colors of red, green, and blue, which are used to assign specific colors that can be displayed.[7] In each numerical component, the lower the value, the lower the color brightness, and the higher the value, the higher the color brightness.

3.3.4. L*a*b* color space principle

Colorimeter testing uses the CIE L*a*b* color space, which is widely used in the industry.[8] The CIE L*a*b* color space uses the L* value to represent the brightness of the color, the a* value to represent the green-red value of the color, and the b* value to represent the blue-yellow value of the color. ΔL, Δa, Δb are the differences between the brightness L* and the chromaticity index a* and b* of the carcass sensory evaluation group and the environmental simulation detection experiment.

L* value: the brightness of the object, 0-100 means from black to white, in simple terms, it is the depth of the color; ΔL+ indicates whitish and ΔL- indicates black;

a* value: the red-green color of the object, indicating red, and the negative value indicating green; Δa+ indicates reddish and Δa- indicates greenish;

b* value: the yellow-blue color of the object, positive values indicate yellow, negative values indicate blue; Δb+ indicates a yellowish tinge, and Δb- indicates a bluish tinge.

3.4. Carcass sensory comprehensive evaluation experiment

3.4.1. Fattening period assessment

In order to reduce the error and subjective difference, five raters were selected to conduct independent ratings in the same environment, and the results of the five groups were summarized and analyzed.

The fattening period of beef cattle is the fattening time of beef cattle at the age of 6-16 months, and is graded according to the length of the fattening period.

Table 2. Assessment standards for beef cattle fattening period

grade	Content of the evaluation criteria
A	High-quality beef cattle with a finisher period of 20-24 months (600-720 days)
B	High-quality beef cattle with a fattening period of 10-15 months (300-450 days)
C	Beef cattle with a fattening period of 6-8 months (180-240 days)

3.4.2. Fat content assessment

Meat quality rating is mainly judged by four indicators: fat snowflake morphology[9], muscle color, fat color, and meat elasticity. Among them, fat content refers to the proportion of fat distributed in snowflake-like muscles, and is evaluated according to the criteria shown in the table below, and the evaluation is divided into 6 grades.

Table 3. Fat content grade evaluation standards

Grade	Fat content		
	Evaluation criteria	Refer to the diagram	Fat content
6	Extremely rich	6	30.6% or more
5	Abundant	5	23.6~30.5%
4	Lots of them	4	16.6~23.5%
3	Normal amount	3	9.6%~16.5%
2	Small amount	2	2.5%~9.5%
1	Trace	1	2.4% or less

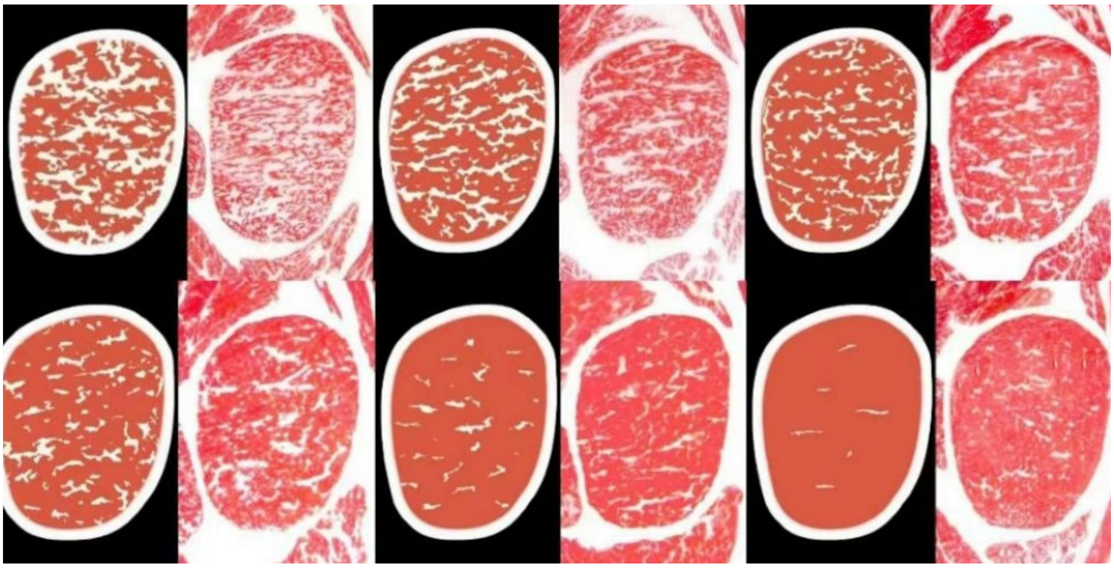


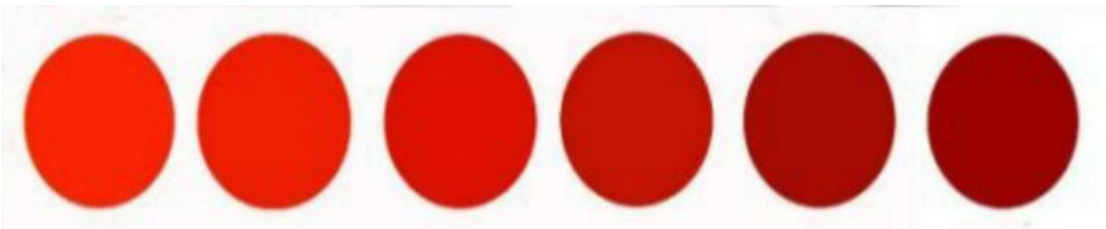
Figure 6. Fat texture map grade Figure 6-1 class

3.4.3. Muscle color assessment

The muscle color rating is based on the depth of the muscle color of the beef cattle carcass section and different positions after acid discharge, and the reference color card is used for comparison, and the reference meat color range is shown in Table 4, and the grade is evaluated according to the visual senses.

Table 4. Muscle color rating standards

Grade	Flesh	
	Refer to the diagram	Color
6	6	Light pink
5	5	Pink
4	4	Light red
3	3	Red
2	2	Scarlet
1	1	Deep black-red



6 5 4 3 2 1

Figure 7. Muscle color Class Figure 6-1 class

3.4.4. Fat color assessment

The fat color grade is mainly based on the color depth of the fat at different positions of the section, using the reference color card comparison, referring to the fat color range in Table 5, and grading according to the visual senses.

Table 5. Fat color rating standards

Grade	Flesh	
	Refer to the diagram	Color
6	6	Snow white
5	5	White
4	4	Yellowish-white
3	3	Buff
2	2	Yellow
1	1	Dark yellow

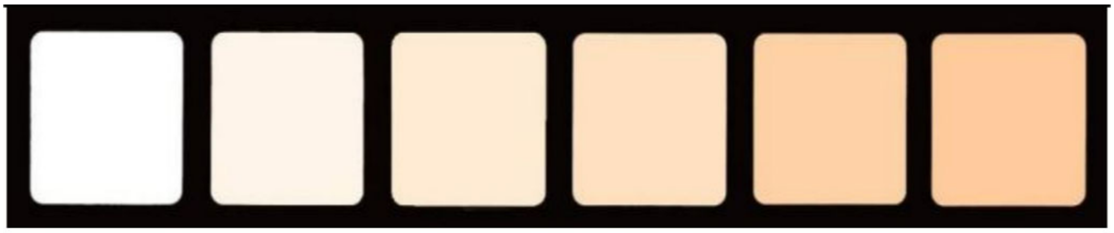


Figure 8. Fat color grades Figure 6-1 class

3.4.5. Evaluation of meat quality traits

The evaluation of meat quality is mainly based on the elasticity and tenderness of meat quality, as well as the delicacy of texture and texture, and is judged by sensory, visual, and tactile senses. Refer to Table 6 for grading.

Table 6. Evaluation standards of elasticity and texture of meat

Grade	Composite traits	
	Elasticity	Sense organ
6	The elasticity is good	Intermuscular fat is normal and the texture distribution is fine
5	Good elasticity	Intermuscular fat is normal and evenly textured
4	Good elasticity	Intermuscular fat is normal and texture distribution is normal
3	The elasticity is good	Intermuscular fat is normal and texture distribution is abnormal
2	Weak elasticity	The intermuscular fat is large and the texture distribution is abnormal
1	Inelastic	The intermuscular fat is too large and the texture distribution is not normal

3.5. Environmental simulation testing experiments

The environmental simulation experiment simulated five groups of different environmental variables: normal bright environment, dim and no light environment; Normal indoor light source but side light source interferes with the environment, normal indoor light source but top light interferes with the environment; The image acquisition environment is black background and white background; Frame when limiter; The framing spacing is 5 cm, 15 cm and the time distance is fixed with the device. The experiments were carried out in two groups with photographic grading equipment and without photographic grading equipment, and each group of experiments was carried out by using a colorimeter and an intelligent grading system for beef cattle carcass. The test was repeated three times, each group of data was recorded, and the final result was averaged. L*a*b* values, RGB and HSV color space parameters were used for reference comparison with the actual parameters of the carcass sensory rating results of beef cattle. The analysis of variance method was used to analyze the data, and the data difference and stability of the two groups with and without equipment were compared. Referring to the actual color parameter data of the sensory group as the main basis for evaluation, the question of whether the equipment can effectively assist the grading process and whether the equipment is feasible is tested.

It is expected that the results of environmental simulation test experiments show that the color parameters of the non-equipment group are much different from the actual situation due to the interference of adverse environmental factors, and even deviate from the actual color of beef cattle carcass.[10] There is a device group that can relatively avoid environmental interference, which is in line with the actual sensory flesh color and fat color.

3.5.1. Simulation detection of light and dark environmental impacts

The light and dark environments were simulated under the normal indoor light source and indoor complete shading during the day, and the carcass flesh color was detected in the two groups of environments by using graded photographic equipment, and the three groups of parallel experiments were repeated, and the experiments without equipment were operated as above. The colorimeter is recorded to display various data, and the images are collected and imported to the grading cloud platform for color parameter analysis.

3.5.2. Adverse light source affects simulated detection

In the normal indoor environment, the flashlight was used to simulate the influence of different light sources on the left and right sides of the beef cattle carcass sample and the position of the top light directly above, and two sets of tests were carried out in the two environments, the colorimeter displayed various data were recorded, and the images were collected and imported into the grading cloud platform for color parameter analysis.

3.5.3. The background color affects the simulated detection

In the actual grading operation, most of them are workshops, factories or laboratories, and the background is relatively monotonous and uniform, mostly light or white. At the same time, Peng Zengqi et al. studied the operation of putting cattle carcasses into the camera obsca for detection. Therefore, the relatively common black and white background was used to analyze the influence of background color on the collection of beef cattle carcass information. Repeat three sets of parallel experiments, record the data displayed by the colorimeter, and collect images with or without equipment and import them to the grading cloud platform for data analysis.

3.5.4. Limiters affect analog detection

In order to reflect the influence of the limiter, the limit with a diameter range of 7.5cm × 7.5cm is used in this experiment, which is smaller than the framing range of the camera equipment. Three groups of parallel experiments were repeated, the data displayed by the colorimeter were recorded, and the images were collected and imported into the grading cloud platform for data analysis.

3.5.5. Framing spacing affects simulation detection

Since the design concept of the camera equipment itself is fixed with the problem of controlling the framing distance, this group of variables is mainly for the no-device group. In the absence of equipment, the image acquisition was carried out with two spacing spacings of 5 cm and 15 cm from the beef cattle carcass to the lens, and the spacing value of the equipment group was fixed, and the three groups of parallel experiments were repeated for data analysis.

4. Analysis of Results

4.1. Analysis of carcass sensory evaluation results

Table 7. List of grade confirmation methods

Grade	Rating criteria			
	Fat content	Muscle color	Fat color	Composite traits
6				
5			√	√
4		√		
3	√			
2				
1				
Results	Level 3			

For example, the fat content in the above table is 3, the muscle color is 4, the fat color is 5, and the meat quality comprehensive trait grade is 5, and the meat quality grade of this part of the beef is 3. The comprehensive evaluation of carcass is a comprehensive evaluation of the fattening period and meat quality grade of beef cattle.[11] The fattening period of beef cattle is rated as A, B and C three levels, and the fattening period of the beef cattle is 22 months, and the carcass comprehensive evaluation result is A3 grade.

The fat content on the surface of the A3 beef carcass was normal, and the snow pattern morphology was good and evenly distributed. The muscle color is four-level bright red, and the R value is in the range of 200-220. The color of the fat is normal white, and the brightness is in the range of 0.85-1. The overall carcass is bright in color, fresh in color, and good in quality.

Table 8. Carcass Grade Classification (18 grades in total)

Grade	Level 6	Level 5	Level 4	Level 3	Level 2	Level 1
A	A6	A5	A4	A3	A2	A1
B	B6	B5	B4	B3	B2	B1
C	C6	C5	C4	C3	C2	C1

4.2. Analysis of the results of environmental simulation and testing experiments

In the environmental simulation detection experiment, the experiments of the equipment group and the non-equipment group were repeated in three groups of parallel experiments, the L*a*b* data displayed by the colorimeter were recorded, and the images were collected and imported into the grading cloud platform for color parameter analysis, the RGB and HSV parameters shown by the system were recorded, and the experimental data obtained were finally taken and their average values were taken, and the final data results were shown in Figure 9 and Table 10 for result analysis.

Table 9. No equipment group environmental simulation detection experiment (1 group)

Color parameters	Variable	Dimly lit environment	Bright environment	Side light source	Front-facing light source	Black background	White background	Limiter	Spacing 5cm	Spacing 15cm
HSV value	H (°)	60	180	180	160	180	2.86	26.6	5.81	180
	S (%)	1	0.32	1	0.18	0.67	0.58	0.11	0.34	1
	V (%)	0.01	0.35	0.35	0.37	0.01	0.28	0.41	0.36	0.21
RGB value	R	2	26	0	15	1	72	198	91	0
	G	2	38	1	17	3	32	183	63	2
	B	0	34	0	14	2	30	207	60	1
L*a*b*	L*	3.7	44.3	48	50.2	30.6	45	42	39	53
	a*	24.5	19.8	19.5	16	11.74	22	17.4	28.7	17.46
	b*	16.7	11.5	16.3	11	9.83	16	20	14	25

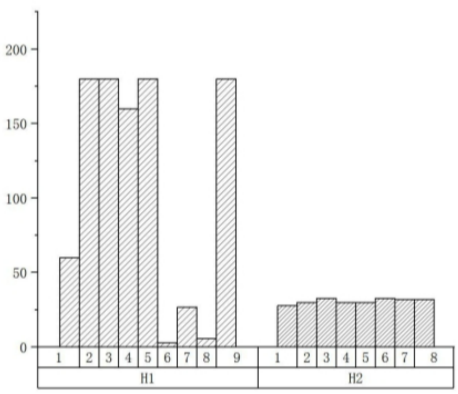
The analysis data shows that each group of data in the non-equipment group shows a large degree of dispersion, large fluctuations, and a large span of color information in different environments, and even deviates from the actual situation, for example, in the environment of the side light source of the no equipment group, the R value = 0, and no red color appears, which is completely inconsistent with the actual situation of sensory testing, which proves that the detection experiment is greatly affected by environmental interference, resulting in large data differences and inaccuracy.

Table 10. Environmental simulation test experiment with equipment group (2 groups)

Color parameters	Variable	Dimly lit environment	Bright environment	Side light source	Front-facing light source	Black background	White background	Limiter	Spacing fixed
HSV value	H(°)	26.69	30	31.73	30.65	29.86	32.73	32	32
	S(%)	0.16	0.19	0.15	0.18	0.16	0.17	0.18	0.17
	V(%)	0.81	0.8	0.82	0.81	0.8	0.82	0.69	0.82
RGB value	R	206	204	208	206	203	208	207	210
	G	199	178	203	196	190	203	170	203
	B	193	165	197	186	182	197	192	185
L*a*b*	L*	38.9	40	40.06	40	39.8	40.5	41	40
	a*	19.6	20	20.05	20	20.15	19.8	22	20
	b*	16.4	17	17.2	17.6	17.44	16.52	16	17

As shown in the table, the data of the equipment group is relatively stable, the fluctuation change is small, the overall parameters are more accurate, and the results are more accurate in line with the carcass sensory inspection parameters.

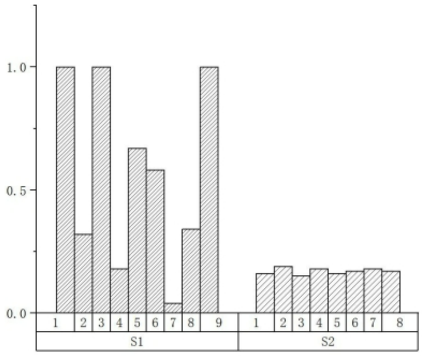
4.2.1. HSV color parameter analysis



*H1 is the H-value data of the non-device group, H2 is the H-value data of the device-based group, and variables 1-9 correspond to the environment variables in Table 9 and Table 10, respectively

Figure 9. Comparison of H value parameters between two groups of devices

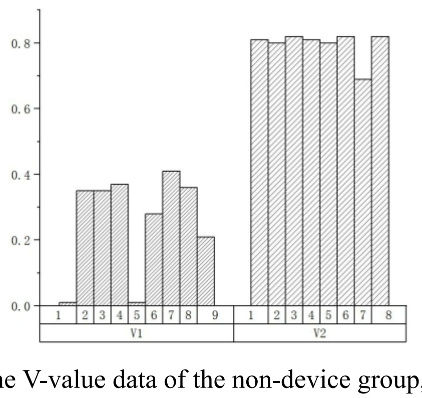
Comparing the two sets of experimental data, it can be seen that the H value hue (Hue) in the HSV value is the highest H value of the limiter group in the non-equipment group, with a value of 206.6 and the lowest value is only 2.86. The degree is larger, indicating that the overall tone is relatively rich and messy in the absence of equipment, and the color is not a single red and white on the surface of the beef cattle carcass. On the contrary, the hue H value of the equipment group was relatively stable, and the overall remained between 29 and 33, and the analysis data showed that the variance was 1.09, the data discrete was small and stable, corresponding to the hexagonal pyramid space, mainly the value angle of the bright red parameter, and compared with the carcass evaluation results, the color range was close to the A3 beef sensory assessment surface fat color bright red and fat white, and the hue information was more accurate. When there is a device, it can better restore the actual hue information of the carcass, which helps to improve the accuracy of the grading results.



*S1 is the S-value data of the non-device group, S2 is the S-value data of the device group, and variables 1-9 correspond to the environment variables in Table 9 and Table 10, respectively

Figure 10. Comparison of S value parameters between two groups of devices

The saturation S value of the non-equipment group was significantly higher than that of the equipment group, and the high saturation value was reached in the case of dim, side light source and spacing of 15cm without equipment, S=1, which means that the color is extremely dark and close to black, which is completely inconsistent with the color of the carcass sensory evaluation. Due to the absence of an external fill light source in the absence of equipment, the image color collected by the overall framing is darker, while the image of the equipment group is quite bright as a whole, the saturation is low, the overall saturation S-value parameter is stable, and the discrete degree is small, and the results obtained are stable to indicate that the beef cattle carcass is graded and photographed. It helps to reduce errors.

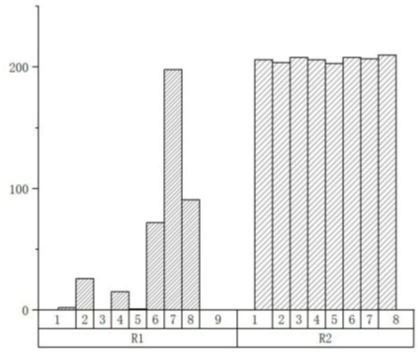


*V1 is the V-value data of the non-device group, V2 is the V-value data of the device-based group, and variables 1-9 correspond to the environment variables in Table 9 and Table 10, respectively

Figure 11. Comparison of V value parameters between two groups of devices

The brightness of the V value shows an obvious trend of higher value of the device group, because the closer the value of the V value is to 0, the darker the picture, especially the overall image acquisition picture of the no device group is dim, and the V value is generally low and the value fluctuates greatly, indicating that the brightness is unstable and flickering, while the value of the device group is stable and the overall brightness is unified, which proves that the brightness of the light source can be effectively guaranteed to be close and avoid the interference of bad light sources when there is a device. The existence of a grading camera device for beef cattle carcasses can alleviate many of the above problems.

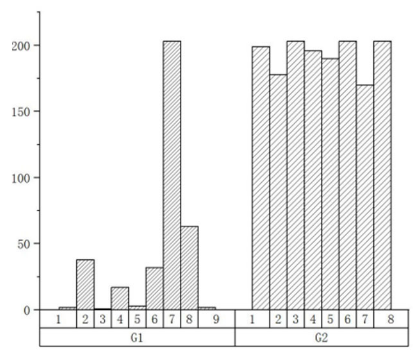
4.2.2. RGB color parameter analysis



*R1 is the R-value data of the non-device group, R2 is the R-value data of the device-based group, and variables 1-9 correspond to the environment variables in Table 9 and Table 10, respectively

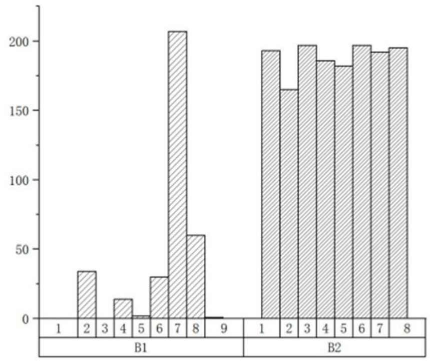
Figure 12. Comparison of R value parameters between two groups of devices

Comparing the RGB color parameters of the two sets of data, it can be inferred that the R value representing red should be at a high level according to the carcass sensory evaluation results of beef cattle carcass grading detection, but the RGB color values of the non-equipment group are unstable, and even the color information is inaccurate, noisy and color confusion occurs. The analysis data shows that the variance of the R-value of the non-equipment group reaches 62.67, which is of a large degree of dispersion, but the variance of the R-value of the equipment group is only 2.12, and the small error value is stable. The R-value of the device group is mainly in the range of 203-210.According to the small fluctuation change, the R value of each group of data is at a high level, indicating that there is more red color information in the carcass to be tested, and the red brightness is bright red, which is in line with the bright red fat color on the surface of A3 beef.



*G1 is the G-value data of the non-device group, G2 is the G-value data of the device-based group, and variables 1-9 correspond to the environment variables in Table 9 and Table 10, respectively

Figure 13. Comparison of G value parameters between two groups of devices

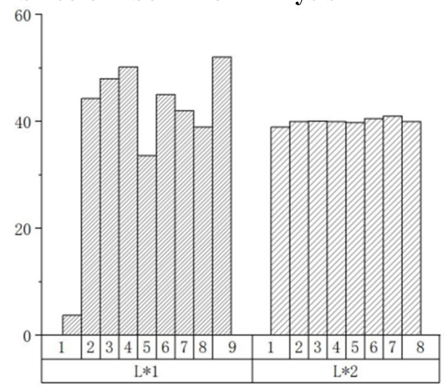


*B1 is the B-value data of the non-device group, B2 is the B-value data of the device-based group, and variables 1-9 correspond to the environment variables in Table 9 and Table 10, respectively

Figure 14. Comparison of B value parameters between two groups of devices

The synthesis ratio of G value and B value of other color parameters was higher than that of R value in the data group without multiple environmental variables in the device group, which proved that the surface of the carcass measured under the environmental simulation test experiment of this group was not bright red muscle color. In the case of the main white fat color, the color information is disturbed when distinguishing the color information, and the color is variegated, resulting in inaccurate results. On the contrary, the equipment group can effectively improve the accuracy of the results by virtue of the auxiliary role of the equipment, which is in line with the actual rating situation and the results are accurate.

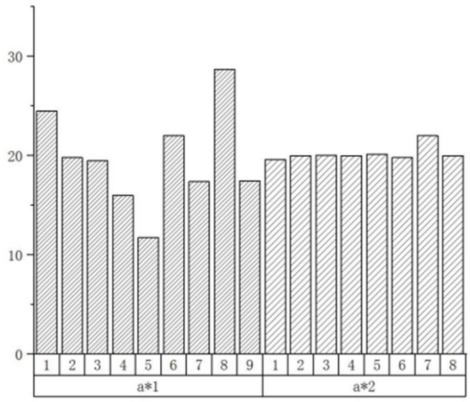
4.2.3. L*a*b* color aberration analysis



*L*1 is the L-value data of the non-device group, L*2 is the L-value data of the device-based group, and variables 1-9 correspond to the environment variables in Table 9 and Table 10, respectively

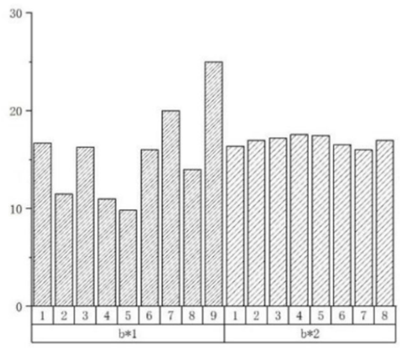
Figure 15. Comparison of L* value parameters between two groups of devices

Chromatic aberration is an important indicator for evaluating the senses and as an important indicator of the freshness of meat.[12] The results of environmental simulation experiments showed that when the total color difference of the meat samples was $P<0.05$ in different environments, there was a significant difference between the existence of the non-equipment group and the existence of the equipment group. There was no significant difference in the overall device group, i.e., $P>0.05$. Because the non-equipment group did not have the lighting equipment, the L* value depended on the brightness and darkness of the environment, and the difference between the ΔL value and the sensory evaluation group was large, and the environment with poor light conditions was mostly ΔL- brightness. The L* value of some device groups fluctuated in the range of 40±1, the value was stable, and the ΔL+ brightness was brighter.



*a*1 is the a-value data of the non-device group, a*2 is the a* value data of the device group, and variables 1-9 correspond to the environment variables in Table 9 and Table 10, respectively

Figure 16. Comparison of a* value parameters between two groups of devices



*b*1 is the b* value data of the non-device group, b*2 is the b* value data of the device group, and variables 1-9 correspond to the environment variables in Table 9 and Table 10, respectively

Figure 17. Comparison of b* value parameters between two groups of devices

The a* and b* values of the non-device group were disturbed to different degrees, and the data of different environmental groups showed individual Δa-green, Δb+ yellowish and Δb- blue, with large fluctuations. There are two sets of data in the equipment group that are stable, and the overall data is Δa+ level, indicating that the overall surface of the carcass is red, which is in line with the sensory evaluation test results. Some equipment groups only fluctuate slightly in the limiter group, and the reasons for this are analyzed, and the fat content of the detection place caused by the limiter is less and the muscle pattern is more, so the A* value is higher and the B* value is lower. In addition, the white background will have a certain degree of brightening effect compared with the black background, and the L* value increases, and the white background is easy to be close to the color of high-quality beef fat, which will interfere with the results, so it is recommended to use the black background as the main one in the actual operation of the grading process.

On the whole, when the equipment group assisted in the detection of meat samples with photographic grading equipment, there was not much difference between the color difference value and the actual sensory evaluation.

4.3. Analysis of the effect of beef cattle carcass grading and photographing equipment

The results of the environmental simulation test experiment were compared with the parameters of the carcass sensory evaluation group, and it can be seen that the whole equipment group is very consistent with the actual sensory evaluation standards, and the grading results are accurate. With the presence of built-in LED fill light, the beef cattle carcass grading and photography equipment can effectively avoid the influence of external light intensity and weaken the interference of the external bright or dim environment. At the same time, the metal shell of the equipment plays a good role in partition protection, isolates external light sources and other adverse influences, and plays the role of image acquisition limit, controls the fixed range of image acquisition and framing, and reduces errors. At the same time, the cost of limiter equipment and the operation of the external limiter are reduced, saving time, effort and reducing costs; The groove structure on the top surface of the device can effectively assist in quickly fixing the camera position when taking pictures, find the appropriate position angle, and reduce manual assistance. The built-in sensor of the device can effectively sense and control the framing distance range, control the framing distance consistently, and ensure the image acquisition quality. Therefore, it can be concluded that the beef cattle carcass grading photography equipment can effectively avoid the influence of external objective environmental factors, as well as the subjective operation or the subjective influence of other grading personnel, improve the grading efficiency, and increase the objective authenticity of the results. In the process of grading and taking pictures, it can effectively assist the grader to operate, and can be completed by a grader alone, saving time and effort, saving manpower and material resources, saving operating costs, improving economic benefits, increasing the credibility and objectivity of the results, promoting the orderly and efficient development of the industry, avoiding the chaos of photo grading on the market today, ensuring the reasonable, orderly and efficient development of the beef carcass market, and improving the competitiveness of China's beef market.[13]

5. Closure and Outlook

The beef cattle carcass grading and photographing equipment designed and developed by the design and research can effectively solve the problems of external adverse environmental light source interference, cumbersome grading operation requirements, unstable photo capture, inaccurate analysis results and lack of operation automation in the process of beef cattle carcass grading sampling and photography, and can effectively improve the technological innovation and transformation of scientific and technological achievements in the direction of beef cattle carcass grading and photographing equipment. If it is put into production and use in the future, it can save the cost of operating equipment, promote economic benefits, increase enterprise income, improve work efficiency and reduce labor intensity, enhance the objectivity and reliability of grading results, and then enhance the comprehensive industrial competitive advantage of enterprises, and enhance the innovation level and competitiveness in the field of beef cattle carcass grading equipment and informatization in our province and even in China. Alleviate the current chaos that there is no unified standard for beef cattle carcass grading in China, standardize operations, improve the international competitiveness of China's beef cattle industry, and achieve multilateral development.

Due to my limited ability, the current beef cattle carcass grading photography equipment is still in the experimental stage, the follow-up to improve the ability, will continue to improve the structural design, and strive to achieve multi-faceted comprehensive application, reduce production costs, and promote the standardization of beef cattle industry, standardized grading production.

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