Non-Destructive Evaluation of Carcass Characteristics in Live Cattle with a Color Scanning Scope

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Introduction

Beef is costly in Japan because beef cattle take a longer period of fattening than other animals for edible meat. If it is possible to know accurately quantity and quality of the beef during the process of breeding and fattening, the appropriate time for slaughtering can be detected. As the result, excessive fat and fattening period are avoided, and efficient use of feed is made possible. Furthermore, that technique is applicable to selection of bulls.

Quantity and quality of meat in living animals are customarily estimated mainly based on subjective observation of the outlook of animals. However, there are many methods of objective estimation. Some of them are biological examination and physical methods. One of the physical methods utilizes an ultrasonic wave[1-5,8-12]. There are many reports on the measurement of subcutaneous fat thickness and cross-sectional area of the *M. longissimus thoracis* of beef cattle by means of ultrasonics[1-5,8-12]. More recent attempts to measure marbling score of the *M. longissimus thoracis* of Japanese Black cattle have been successful. However, in these cases the measurement was done with the picture taken by a Polaroid camera with monocolor photographs[8-12]. Since these photographs were of small size, it is difficult to get precise estimation. Due to the characteristics of ultrasonic wave, such as many reflections and multiple reflections, there are many limitations in taking pictures. Recently, the color scanning scope has been developed by the National Institute of Animal Industry and Kaijo Denki Co., Ltd. With this new device, more quick and accurate determination than ever was made possible.

This paper deals with the prediction of carcass traits by *in vivo* characteristics, especially, the fat percentage of the *M. longissimus thoracis*.

Experimental procedures

Fourteen Japanese Black steers, eight Holstein steers and eleven Holstein cows were used in this study. Those cattle were fed at the National Institute of Animal Industry and the Chiba Prefectural Animal Husbandry

Table 1. General aspects of animals used for the study

Breed of animals		Age (months)	Live weight (kg)	Warm carcass weight (kg)	Dressing percent (%)
Japanese Black steers	(14)	41.8±15.5	645.4± 44.8	407.0±32.9	63.3±2.1
Holstein steers	(8)	37.1±10.6	688.8±140.8	420.7±89.8	61.0±1.1
Holstein cows	(11)	30.4±16.1	690.4± 97.3	412.3±68.2	59.8±2.0
Total	(33)	36.9±15.5	670.7± 96.5	412.1±63.2	61.6±2.5

Values represented mean ±standard deviations.
Numerals in parentheses indicate the number of animals used.

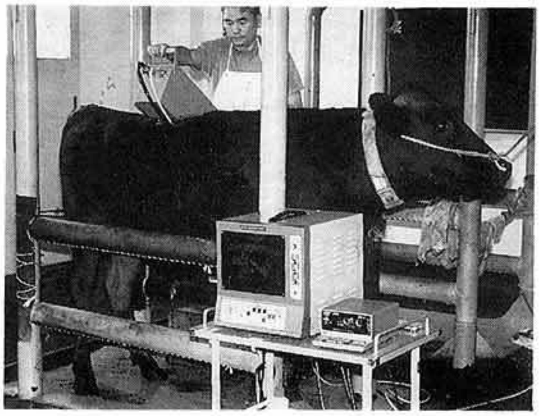

Plate 1. The color scanning scope USL-21 in operation with the display, the prove with guide, and the recorder

Center. They were slaughtered at the slaughterhouse of the National Institute of Animal Industry and the Narita commercial abattoir. Their general aspects are shown in Table 1. These cattle were scanned at the region between the 13th rib and the first lumbar nearly one week before the slaughter by the color scanning scope USL-21 (Kaijo Denki Co., Ltd.). This scanning region was a good position for measuring the *M. longissimus thoracis* from other portions (Plate 1).

This instrument provides sonar pulses emitted from the sensor contacted with the skin of a living animal. The reflecting signals are classified into strong and weak echoes with seven different colors for the CRT color display. The sensor moves automatically with repetition of the pulse emission and receiving. The picture display speed is synchronized with the sensor shifting speed. This instrument is equipped with a one-megacycle transducer. It provides four adjusting dials of TVG (time variable gain)-gain, TVG-level, TVG-start and sensitivity for getting a clear picture with seven different colors (red, orange, yellow, green, violet, white and blue) according to intensity of echoes. For estimating fat percentage of the *M. longissimus thoracis*, the operational conditions were fixed as TVG-gain 3, TVG-level 2, TVG-start 0, and sensitivity 2 according to the previous report[12]. The CRT display picture signals were fed into a computer by the method of RS-232C for rapid calculation. The figures of the computer were displayed with seven colors (red, yellow, purple, green, light blue, white and blue) corresponding to the colors of the CRT picture. The computer CRT display provides a mouse for measuring the subcutaneous fat thickness, the area and fat percentage of the *M. longissimus thoracis*. After slaughter, the subcutaneous fat thickness and the cross-sectional area of the *M. longissimus thoracis* were measured at the corresponding carcass region by a measure and a planimeter. For ether extraction, the 13th rib portion was used to analyze the fat percentage after trimming the surrounding fat.

Results and discussion

1) Estimating the subcutaneous fat thickness

Mean values of the subcutaneous fat thickness over the *M. longissimus thoracis* between the 13th rib and the first lumbar estimated

Table 2. Values estimated of subcutaneous fat thickness of *M. longissimus thoracis* between the 13th rib and the first lumbar of beef cattle

Breed of animals		Estimated (mm)	Actual (mm)	Correlation coefficients
Japanese Black steers	(14)	10.2±3.5	13.8±4.4	0.85**
Holstein steers	(8)	6.9±1.9	6.8±3.0	0.95**
Holstein cows	(11)	11.3±3.8	16.0±5.3	0.59*
Total	(33)	19.8±3.7	12.7±5.7	0.79**

See the footnote of Table 1.
** $P<0.01$, * $P<0.05$.

Table 3. Cross-sectional area of *M. longissimus thoracis* between the 13th rib and the first lumbar of beef cattle

Breed of animals		Estimated (cm^2)	Actual (cm^2)	Correlation coefficients
Japanese Black steers	(14)	88.7± 7.8	88.4± 5.5	0.85**
Holstein steers	(8)	76.7± 7.6	77.6± 6.4	0.90**
Holstein cows	(11)	69.3±10.6	70.0±11.1	0.98**
Total	(33)	79.3±12.3	79.6±12.4	0.95**

See the footnote of Table 1.
** $P<0.01$.

from the figures of the computer CRT display are presented in Table 2. The fat thickness estimated with the color scanning was significantly correlated with that actually measured in each group of cattle. This result agrees with other reports[1-5,8-10]. However, the estimated thickness showed a tendency to be slightly smaller than the thickness actually measured. This difference may be caused by the fact that the subcutaneous fat was pressed strongly with probes put on the skin in the former case.

2) Estimating the cross sectional area of M. longissimus thoracis

Plate 2 shows one of the computer figures taken from the CRT display of the color scanning scope. The relationship of the area estimated from the computer figures to the actually measured area is shown in Table 3. The Japanese Black steers had the largest cross-sectional area with the mean of 88.4 cm^2, followed by 77.6 cm^2 of Holstein steers, and 70.0 cm^2 of Holstein cows. Very high significant correlations between the estimated areas and the actually measured areas were demonstrated in Table 3. This result is in agreement with other reports[1-5,8-10]. However, the correlation coefficients shown in this study was much higher than those of other reports. This difference may be due to the use of the color scanning scope.

As mentioned by Hedrick et al.[5], after getting measurements from the picture, it was necessary to draw subjectively the medial end and a portion of the lateral end of the *M. longissimus thoracis*. The dorsal and ventral sides of the muscle were accurately defined. However, it is difficult to distinguish the border between the *M. multifidus dorsi* and the *M. longissimus thoracis*. Especially, as shown on Plate 2, many dots which look like a band appear on the picture. Then, we traced a line along the central portion of the band, and the line was regarded as the boundary between the muscles. Similarly, we traced a line which is regarded as the boundary between the *M. iliocostalis* and the *M. longissimus thoracis*, by taking red dots showing the 13th rib bone and dots showing the intermuscular fat into consideration. Furthermore, as it was observed that the red color portion showing the upper end of *M. longissimus thoracis*, was partly interrupted or became thin, that portion was taken as a mark for the lateral of the muscle. By this method, the cross-sectional area of *M. longissimus thoracis* can be measured quickly, irrespective of any shape of the cross-sectional area.

3) Estimating the fat percentage of the M. longissimus thoracis from the computer figure

It was tried to estimate the fat content of

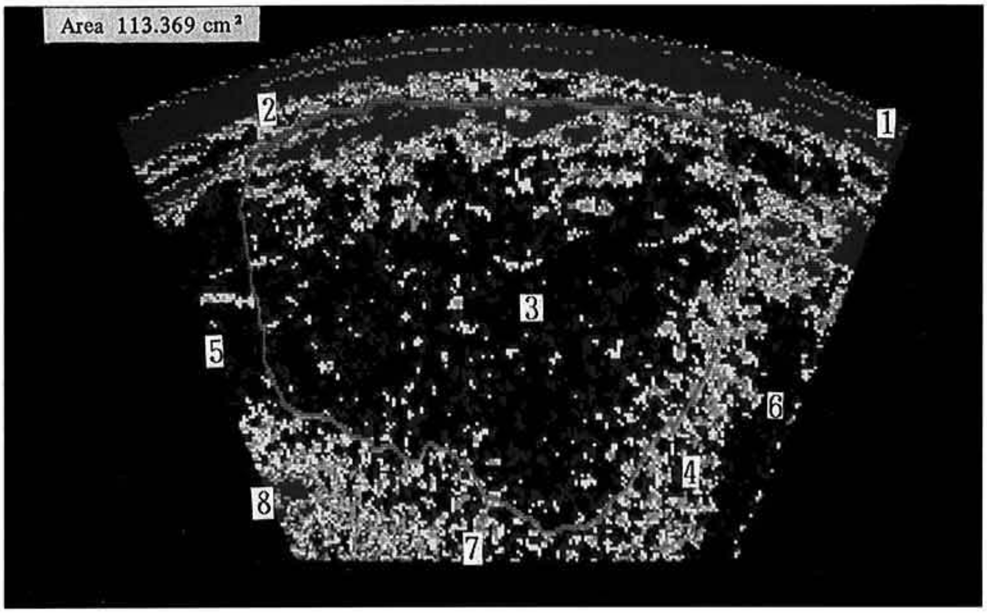

Plate 2. The *M. longissimus thoracis* is surrounded with a green line in the CRT display's figure between the 13th rib and the first lumbar in live beef cattle.
1: Skin, 2: Subcutaneous fat, 3: *M. longissimus thoracis*,
4: *M. multifidus dorsi*, 5: *M. iliocostalis*, 6: *Processus spinalis*,
7: *Procc. transversi*, 8: Rib bone.

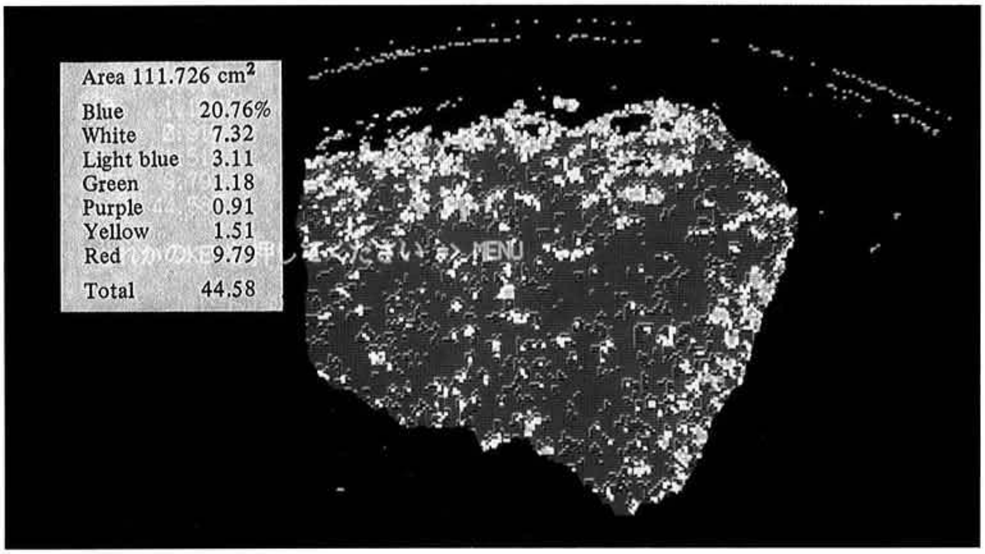

Plate 3. The number (shown by %) of dots of each color in the *M. longissimus thoracis* of Plate 2 is indicated after surrounded with a red line in the CRT display's figure between the 13th rib and the first lumbar.
Black color of the *M. longissimus thoracis* in Plate 2 was turned to red color for calculating the percentage of each color dots by a computer, and Red did not indicate the red portion of this picture.

Table 4. Correlation coefficients between fat percentage and percentage of dots of each different color on *M. longissimus thoracis* between the 13th rib and the first lumbar of beef cattle

Breed of animals		Blue	White	Light blue	Green	Purple	Yellow	Red	Total
Japanese Black steers	(14)	0.76**	0.60*	0.46	0.38	0.33	0.18	0.05	0.47
Holstein steers	(8)	−0.52	−0.33	−0.22	−0.19	−0.23	−0.44	−0.13	−0.22
Holstein cows	(11)	0.29	0.30	0.26	0.20	0.12	−0.01	−0.24	−0.37
Total	(33)	0.39*	0.30	−0.10	0.18	0.08	−0.01	−0.23	0.18

See the footnote of Table 1.
** $P<0.01$, * $P<0.05$.

the *M. longissimus thoracis* from percentages of seven color dots shown in the figures. Estimating the marbling score from picture and figures was already done by Harada et al.[2,3] and Yoshitake et al.[12]. However, they estimated subjectively the marbling score by using mono-color photographs and figures. Actually, it is difficult to estimate objectively the marbling score itself. However, it is well known that the marbling score is closely related to fat contents of the muscle[7]. Then, we tried to estimate the fat contents of the *M. longissimus thoracis* by combining with the result of analysis by a personal computer. The percentages of each color dot after surrounding the *M. longissimus thoracis* in Plate 2 by using the mouse are presented in Plate 3. As shown in Plate 3, however, black color of *M. longissimus thoracis* in the Plate 2 turned to red color for calculating the percentage of individual color dots by a computer. The red did not show the red portion of this picture.

The relationship between percentages of each color dot and fat contents of the *M. longissimus thoracis* in each breed is presented in Table 4. It is clear in the table that the percentage of blue dots shows high correlation coefficients to the fat content. The correlation in Japanese Black steers is as high as 0.76, while that in Holstein is low. The blue dot means the weakest echo in various echoes and shows a pattern similar to the marbling pattern observed actually on the same portion of carcass. Then, the blue dot percentage was used to estimate the fat content in the *M.*

Table 5. Fat percentage and blue color dot percentage of *M. longissimus thoracis* at the portion of the 13th rib of beef cattle

Breed of animals		Estimated (%)	Actual (%)
Japanese Black steers	(14)	17.2±3.0	12.9±4.9
Holstein steers	(8)	5.2±2.0	4.4±2.0
Holstein cows	(11)	18.1±2.4	5.8±1.3
Total	(33)	17.0±2.8	8.5±5.1

See the footnote of Table 1.

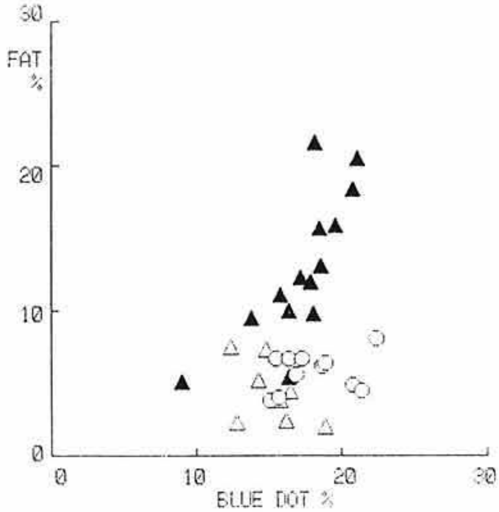

Fig. 1. Relationship of crude fat content to blue dot percentage in the *M. longissimus thoracis* between the 13th rib and the first lumbar of cattle
▲, △ and ○ indicate Japanese Black steers, Holstein steers and Holstein cows, respectively.

longissimus thoracis. The relationship of crude fat to the blue dot percentage in the *M. longissimus thoracis* between the 13th rib and the first lumbar of cattle is presented in Table 5 and Fig. 1.

The close relationship was found with the Japanese Black cattle but not with Holstein. This difference is attributed to the fact that the fat content of the Holstein was very low, as compared with that of the Japanese Black steers. It was less than 10% in the Holstein. In spite of such a low fat content in the Holstein, there are many blue dots in the *M. longissimus thoracis* figures. It seems that there is some difference in skin characteristics between them. The thickness of skin and subcutaneous fat effects the characteristic of the echoes. The skin of Japanese Black steers tends to be thicker than Holstein skin. As shown in Table 2, the average of the subcutaneous fat thickness of the Japanese Black steers is 13.8 ± 4.4 mm, whereas that of Holstein steers is 6.8 ± 3.0 mm. The shape of *M. longissimus thoracis* of Holstein was small and thin as compared with that of Japanese Black cattle. That muscle is located at a shallow portion as compared with Japanese Black cattle. The characteristics affect the reflection echo and hence give different figures.

The other reason is a tiny difference in velocity of echo and density between muscle tissues and fatty tissues. Hence, it is difficult to distinguish fatty tissues from muscle tissues by reflection echoes. There are also many other echoes in the muscles, for instance, multiple reflection and boarding reflection. We also consider that the minimal size of fatty tissues (in muscle tissues) which can be recognized is about 1.5 mm, at largest. Because, this instrument generates ultrasound of 1 MHz and the velocity of the ultrasound in muscle is about 1,500 m/s. We consider that it is impossible to distinguish fatty tissues smaller than 1.5 mm in size with this instrument.

In Japan, the cutting region for carcass of the commercial trade was amended to be the region between the 6th and 7th rib bones, since April in 1988. Therefore, it is desirable to make the estimation at this portion. However, it is very difficult to make the estimation at this portion because the *M. longissimus thoracis* at this portion is covered by many muscles and fat. Hence, we consider that the portion between the 13th rib and the first lumbar is superior to the amended one. The cross-sectional area of *M. longissimus thoracis* tends to gradually increase from the top to the anterior of cattle and also there are differences in fat contents in it[6]. The center portion of *M. longissimus thoracis* has a lower fat percentage than the edge of the muscle.

Fat content of the 13th rib longissimus portion was well predicted by using multiple regression equations. We used the following estimating factors of the subcutaneous fat thickness: area of *M. longissimus thoracis*, blue dot percentage of the figure, age and live weight. The multiple equations are as follows:

Y (fat percentage of *M. longissimus thoracis*, %) $= -0.063$X (age month) -0.014X (live weight, kg) $+ 0.462$X (subcutaneous fat thickness, cm) $+ 0.317$X (area of *M. longissimus thoracis*, cm^2) $+ 1.772$X (blue dot percentage in the CRT figure, %) -35.33, $R^2 = 0.76$;

Y (fat percentage of the *M. longissimus thoracis*, %) $= -0.009$X (live weight, kg) $+ 1.593$X (blue dot percentage, %) -9.147, $R^2 = 0.61$.

It is concluded that the subcutaneous fat thickness, and the area and the fat content of the *M. longissimus thoracis* can be estimated objectively and easily from figures of the CRT display by combining the color scanning scope USL-21 and a personal computer. However, more study is necessary to increase accuracy in estimating meat quality, for instance, by adjusting the measuring conditions and further improving this instrument.

Summary

A color scanning scope USL-21 was used

for estimating the subcutaneous fat thickness, the fat percentage and the cross-sectional area of *M. longissimus thoracis* in live cattle without slaughter. Fourteen fattened Japanese Black steers, eight Holstein steers, and eleven fattened Holstein cows were scanned at the region between the 13th rib and the first lumbar about one week before slaughter. The picture signals obtained from the scanning scope were fed into a computer for rapid calculation of the subcutaneous fat thickness, the area and the fat percentage of the *M. longissimus thoracis*. For estimating the fat percentage of the *M. longissimus thoracis*, the operational conditions were fixed (TVG-gain 3, TVG-level 2, TVG-start 0, sensitivity 2). After slaughter, the subcutaneous fat thickness, the cross-sectional area and the fat content of the *M. longissimus thoracis* were measured at the corresponding carcass region using a measure, a planimeter and the ether extraction method, respectively. The color-scanning estimates of the subcutaneous fat thickness and the cross-sectional area of the *M. longissimus thoracis* agreed considerably well with the actual carcass measurement in each animal, showing $r = 0.85$ and $r = 0.95$ respectively. A high correlation coefficient was obtained between color-scanning estimates based on blue dot percentages and the actual fat percentage of the *M. longissimus thoracis* figures with fattened Japanese Black steers ($r = 0.76$), whereas no such a high correlation was observed with Holstein steers and cows. This result shows that the color scanning scope is a useful instrument for estimating the meat quality of live beef cattle of Japanese Black steers. However, further study is needed to increase accuracy of meat quality estimation.

References

1) Kumazaki, K. & Harada, H.: Studies on performance of meat production of Japanese beef cattle with use of ultrasonics. 1. The ultrasonic measurement of rib-eye area, fat thickness and marbling of Japanese beef cattle. *Miyazaki Nōhō.*, **23**, 9–15 (1976) [In Japanese with English summary].
2) Harada, H. & Kumazaki, K.: Relationship between fat thickness, cross sectional area of *M. longissimus thoracis* and marbling score, and their ultrasonic estimates. *Jpn. J. Zootech. Sci.*, **51**, 261–266 (1980) [In Japanese with English summary].
3) Harada, H.: The use of ultrasonic to estimate carcass traits in live beef cattle. *Miyazaki Nōhō.*, **29**, 1–65 (1982) [In Japanese with English summary].
4) Harada, H., Moriya, K. & Fukuhara, R.: Early prediction on carcass traits of beef bulls. *Jpn. J. Zootech. Sci.*, **56**, 250–256 (1985) [In Japanese with English summary].
5) Hedrik, H. B. et al.: Estimation of rib-eye area and fat thickness of beef cattle with ultrasonics. *J. Anim. Sci.*, **21**, 362–365 (1962).
6) Ozutsumi, K. & Okada, M.: On the development of *longissimus* muscle in Holstein steers during the fattening period after grazing. *Jpn. J. Zootech. Sci.*, **53**, 116–123 (1982).
7) Ozutsumi, K. et al.: Relation of meat characteristics and carcass grades in commercial beef. *Jpn. J. Zootech. Sci.*, **56**, 1–6 (1985) [In Japanese with English summary].
8) Stouffer, J. R., Wallentine, M. V. & Wellington, G. H.: Ultrasonic measurement of fat thickness and loin eye area on live cattle and hogs. *J. Anim. Sci.*, **18**, 1483 (1959).
9) Stouffer, J. R. et al.: Development and application of ultrasonic methods for measuring fat thickness and rib-eye area in cattle and hogs. *J. Anim. Sci.*, **20**, 759–767 (1961).
10) Tempel, R. S., Ramsey, C. B. & Patterson, T. B.: Errors in ultrasonic evaluation of beef cattle. *J. Anim. Sci.*, **24**, 282 (1965).
11) Watanabe, A. et al.: Estimation of the *M. longissimus lumborum* area of cattle with a color ultrasonic scanning scope using a mechanical arc scan. *Jpn. J. Zootech. Sci.*, **57**, 813–817 (1986) [In Japanese with English summary].
12) Yoshitake, M. et al.: Measurement of marbling score and area of the *M. longissimus thoracis* by a color scanning scope. *Nikuyōgyu Kenkyukaihō*, **38**, 32–33 (1984) [In Japanese].

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