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黒毛和種枝肉形質推定のためのコンピュータ画像解析による生体体積および密度測定法

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Abstract Video images from three directions (rear, side and dorsal view) of forty Japanese Black steers were recorded by video camera, and stored in a computer memory. Live body contour lines were detected, and the volume and the density of live body portions were estimated via the computer program that was developed by the authors. Twelve live body measurements, fifteen carcass trait measurements and subcutaneous fat thickness measument via the ultrasonic method were used in this study. The relationships between those body dimensional traits and image traits were investigated. Mean values for the volume and the density of body portions were 0.35 m^3 and 1.608 g/cm^3, respectively. Body portion volume significantly and positively affected body dimensional traits. Body portion density had significant and negative correlations with the subcutaneous fat thickness of a live body. Significant improvement in the R^2-value was obtained for the yield score by including body portion volume and density in multiple regression equations that estimate carcass traits.

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Key words : Image analysis, body volume and density, Japanese Black, prediction of carcass traits

It has been reported that the body measurement traits of live cattle are useful for predicting quantative and qualitative carcass traits (carcass traits)[7]. YAMAZAKI *et al.*[13] indicated that the correlation between fattening grade (Japan meat grading standard) and intramuscular fat was highly positive for Japanese Black and Holstein steers. SUZUKI *et al.*[11] developed the volume metric procedure for swine using a compression chamber, and indicated that well-fattened swine had a tendency to show low density. Significant relationships between qualitative carcass traits and rump shapes which were numerated by computer image analysis were reported by KUCHIDA *et al.*[7].

As mentioned above, it might be possible to predict carcass traits using body volume and density that have been estimated via the image analysis method. The purpose of this study is to develop procedure for estimating the volume and density of a live body using the image analysis method, and to show how feasible this method is for predicting carcass quality and quantity.

Materials and Method

Live body and carcass traits were measured on forty Japanese Black steers sired by four bulls that were used for a progeny testing project in Miyagi prefecture. Body measurements and video photography of live steers were carried out two days before slaughter. Body measurement traits were body height, height at hip cross, body length, chest girth, chest depth, chest width, rump length, hip width, thurl width, pin bone width, shank circumference and body weight.

Carcass weight, dressing percentage, rib-eye area, rib thickness, subcutaneous fat thickness, yield score, intermuscular fat thickness, carcass length, beef marbling standard number (BMS), beef color standard number (BCS), meat luster, firmness, texture, beef fat standard number (BFS) and fat luster quality were measured as carcass traits[5].

Video images from three directions (side, rear and dorsal) were recorded by a color video camera (Sony Co. Ltd. : CCD-V700) as shown in Fig. 1. The video camera for the dorsal view was set high enough to take an image of the whole body, and was remote-controlled. The side and rear images were taken at a 0.75 m height from ground level.

After conversion from analog to digital, the video images were stored in a computer memory. The contours of the live body were semi-automatically detected by a system which was developed by KUCHIDA *et al.*[6,7], and the noise in these lines was manually corrected. A personal computer (PC-9801 : NEC Co. Ltd.) was used for image analysis. A computer program using C language[4] was also developed, based on coordinate transformation and the method of KUCHIDA *et al.*[6,7].

SUWA[10] demonstrated that it is possible to estimate the volume of an object by the method of dot or plane analysis. The measuring procedure for volume by image analysis is

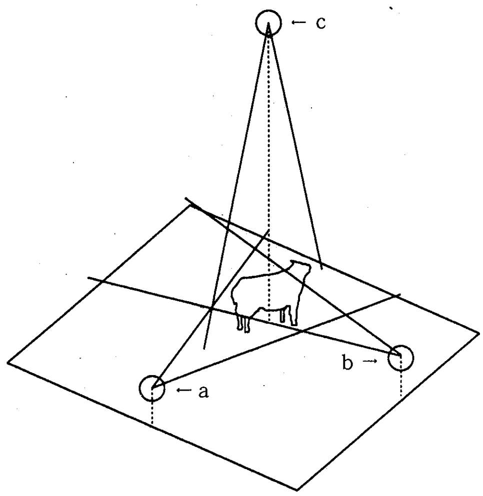

Fig. 1. Video photographing method for live cattle from the three directions
a : Camera point for rear view.
Distance 5 m from center of the cattle
Height 0.75 m
b : Camera point for side view.
Distance 5 m from center of the cattle
Height 0.75 m
c : Camera point for dorsal view
Height 6 m from ground

indicated as follows, and in Fig. 2.

1. Maximum width on the horizontal axis (X-axis), maximum height on the vertical axis (Y-axis) and the area of the object were measured via the rear direction image.
2. Height (h) at the point of arbitrary depth on the Z-axis was measured via the side direction image.
3. Body volume was calculated as per the following equation,

$$V=\frac{S}{ab}\int_0^l hw\Delta z$$

where,

V : estimated volume,
S : the number of pixies of the rear view,
a : maximum height on the vertical axis of the rear view,
b : maximum width on the horizontal axis of the rear view,
h : the height of the side view at any posi-

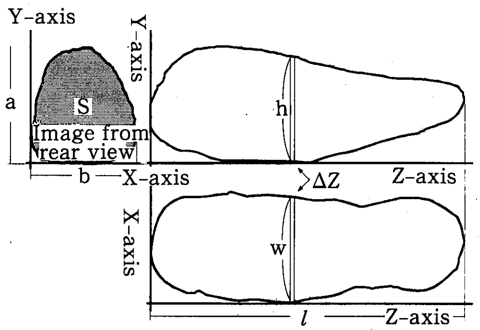

Fig. 2. Estimation method of the volume in this study applied to the clay model
S : number of pixies of the rear view
a : the maximum height on vertical axis of the rear view
b : the maximum width on horizontal axis of the rear view
h : the height of the side view at any position on Z-axis oriented vertebrate
w : the width of the dorsal view on Z-axis oriented vertebrate
l : total length of the body on Z-axis
Δz: the minute length on Z-axis

tion on a Z-axis oriented vertebrate,
w : the width of the dorsal view at any position on a Z-axis oriented vertebrate,
l : total body length on the Z-axis,
Δz : minute length on the Z-axis.

In order to verify this method, some clay models were examined. The volumes of the models were measurable by sinking them into water.

This method cannot estimate the volume of a complex body, therefore it is necessary to eliminate the depression or contortion part of the image. In this method, the front legs were manually cut in the image analysis process. According to our investigation of the coordinate on the Z-axis of head and rear legs about side view, the area of a live body without the influence of rear legs or head was from 25% to 65% of total body length (l : in Fig. 2) from the hip end of the side image. And the volume of this part was defined as the volume of the body portion. The density of the body portion was defined as the quotient of the body portion volume by the weight of the live body.

Ultrasonic measurements for subcutaneous fat thickness were performed at six points based on the method reported by NAGAMINE *et al.*[8]. Four points beside the median line and two points on the abdominal side were selected for subcutaneous fat measurement. Three ultrasonic measurement traits were analyzed in this study ; the total thickness of all six points, the total thickness of four dorsal points and the total thickness of two abdominal points.

Multiple regression analyses for predicting carcass traits were performed, and the independent variables were body measurement traits, the volume and the density of body portions and ultrasonic measurements of subcutaneous fat thickness. The SAS[9] package was used to analyze and to test significance for this study.

Results and discussions

The precision of volume estimation for the clay model by this method is shown in Table 1. The error percentages in the estimation are within 3%. This indicates that this method is accurate enough to estimate the volume of live cattle. KUCHIDA *et al.*[7] reported that this image analysis method can measure parabola and width scores for live cattle with high accuracy, and that this volume measuring method might be applicable for live cattle measurement.

Mean values for the volume and the density of body portions were 0.35 m^3 and 1.608 g/cm^3, respectively. TAKASHIMA[12] reported that the live density of mice was 1.1 g/cm^3. Since the volume of the body portion is estimated except for the head and limbs in this study, the density of body portion was over-estimated.

The four chemical components that organize a live body, each have their own density (water : 1.0, lipid : 0.9, protein : 1.3, ash : 4.0 g/cm^3)[12]. The density of a whole body can be calculated by the sum of the products of each component

Table 1. Precision of volume measurement by image analysis method

		Target volume[a]	Volume by image analysis method	Error percentage
Model 1	Trial 1	67.0 cm³	68.1 cm³	1.6%
	Trial 2		68.8 cm³	2.7
	Trial 3		67.8 cm³	1.2
Model 2	Trial 1	70.0 cm³	69.6 cm³	−0.6
	Trial 2		70.2 cm³	0.3
	Trial 3		69.0 cm³	−1.4
Model 2	Trial 1	68.0 cm³	67.1 cm³	−1.3
	Trial 2		66.4 cm³	−2.4
	Trial 3		66.3 cm³	−2.5

[a] : Target volumes of clay model were measured by sinking them into water.

Table 2. Correlation coefficients of volume and density of body portions with body and carcass measurements (n=40)

	Body height	Hip cross	Body length	Chest girth	Chest depth	Chest width	Rump length	Hip width	Thurl width	Pin[b] width
Volume[a]	0.391*	0.288	0.640**	0.684**	0.646**	0.645**	0.198	0.344*	0.373*	0.120
Density[a]	−0.114	−0.171	−0.185	−0.153	−0.107	−0.224	0.017	0.088	0.080	0.172
	Shank circum.	**Body weight**	**Fat[c] thick 1**	**Fat[d] thick 2**	**Fat[e] thick 3**	**Carcass weight**	**Dress. percent**	**Rib-eye area**	**Rib thick**	**Subcut. fat[f]**
Volume[a]	0.150	0.808**	0.537**	0.507**	0.453**	0.769**	0.330*	0.338*	0.614**	0.280
Density[a]	0.144	−0.080	−0.395*	−0.425**	−0.252	−0.068	−0.133	0.163	−0.190	−0.035
	Yield score	**Inter. fat[g]**	**Carcass length**	**BMS[h]**	**BCS[i]**	**Meat luster**	**Firm-ness**	**BFS[j]**	**Volume**	**Density**
Volume	0.051	0.394*	0.608**	0.234	−0.109	−0.142	−0.119	−0.022	1.000**	−0.649**
Density	0.100	−0.005	−0.183	−0.042	0.105	0.123	0.061	0.173	−0.649**	1.000**

* : $p<0.05$, ** : $p<0.01$
[a] : Volume and Density : volume and density of body portions calculated by image analysis method.
[b] : Pin width : pin bone width,
[c] : Fat thick 1 : the total thickness of all points measured by ultrasonic method,
[d] : Fat thick 2 : the total thickness of four dorsal points,
[e] : Fat thick 3 : the total thickness of two abdominal points,
[f] : Subcut. fat : Subcutaneous fat thickness of carcass,
[g] : Inter. fat : Intermuscular fat thickness, [h] : BMS : beef marbling standard, [i] : BCS : beef color standard,
[j] : BFS : beef fat standard
Texture and fat luster quality were same value in each steer.

percentage and its density. In particular, fat density is lowest among these four components.

The chemical components of the body can be estimated by live body density. ADAM and SMITH[1] reported a high and negative correlation coefficient ($r=-0.93$) between body density and lean per weight ratio on a slaughtered swine. Similarly, DAHMS and GLASS[3] reported a high correlation coefficient ($r=-0.95$) be-

Table 3. R^2-value and partial R^2-value of multiple regression analysis for yield score

Dependent variables	Independent variables							
	Body measurements				Volume and density + Body measurements			
	R^2-value	Traits	Part. R^2	Sign	R^2-value	Traits	Part. R^2	Sign
Yield score	0.080	Hip cross[a]	0.080	+	0.285**	Hip cross	0.080	+
						Rump length	0.054	+
						Volume[b]	0.150	+

* : $p<0.05$, ** : $p<0.01$

[a] : Height at hip cross, [b] : Volume of body portion

tween water content and density measured by sinking into water. SUZUKI *et al.*[11] developed a measuring method for body density using a compression chamber, and suggested the relation between swine body density and fat content. Table 2 shows correlation coefficients of the volume and the density of body portions and carcass measurements. The volume of the body portion is significantly and positively affected by body length, chest girth, body depth, body width, body weight and fat thickness. As these traits are related to body size, these positive correlations were expected easily.

Significant and negative relationships were found for the density of body portions with subcutaneous fat thickness measured by the ultrasonic method.

Regression analyses for estimating carcass traits were performed with the volume and the density of body portions, twelve body measurements and three ultrasonic measurements of a live body. The coefficient of determination for yield score improved significantly by taking the volume and the density of body portion into an equation (Table 3). However, much lower R^2-values were obtained by putting these traits into equations for other traits. ANADA *et al.*[2] investigated carcass image analysis on a cross section around the rib-eye muscle, and reported that the most important variable for total fat percentage was fat area in stepwise regression analysis. This positive relationship between the density of the body portion and yield score in multiple regression analysis was in agreement with them.

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黒毛和種枝肉形質推定のためのコンピュータ画像解析による生体体積および密度測定法

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40 頭の黒毛和種去勢牛に対する 3 方向からの画像（後, 横および上方向）が, ビデオカメラにより記録され, コンピュータのメモリー上に取り入れられた. 生体の輪郭線の抽出および生体の部分体積および部分密度の推定は, 著者らにより作成されたコンピュータプログラムで行われた. 生体に関する 12 形質, 15 の枝肉形質および超音波による皮下脂肪厚も測定された. それらの体測定値と画像解析形質との関連性が検討された. 生体部分体積と生体部分密度の平均値はそれぞれ $0.35\,m^3$, $1.608\,g/cm^3$ であった. 生体部分体積は, 体のサイズに関連する形質に対して有意かつ正に影響していた. 生体部分密度と超音波による皮下脂肪厚との間に有意かつ負の相関が認められた. 枝肉形質を推定するための重回帰分析に, 生体部分体積および密度を取り入れることで, 歩留基準値の R^2 値に有意な改善が認められた.

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