Extraction of Computer Image Analysis Information by Desk Top Computer from Beef Carcass Cross Sections[1]

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ABSTRACT : The precision and reliability of the Computer Image Analysis technique using a desk top computer for extracting information from carcass cross section scans was evaluated by the repeatability (R) and coefficient of variation (CV) for error variance. The 6th and 7th ribs cross section of carcasses from 55 fattened Japanese Black steers were used. The image analysis was conducted using a desk top computer (Macintosh-Apple Vision 1710 Display) connected to a scanner and an image capture camera. Two software applications, Adobe Photoshop and Mac Scope were used interchangeably. The information extracted and measured were individual muscle area, circumference length, long and short axes lengths, muscle direction; distance between any two muscle centers of gravity; cross section total area, lean, fat, and bone. The information was extracted after the processes of scanning, digitization, masking, muscle separation, and binarization. When using the Computer Image Analysis technique by desk top computer, proper digitization and selection of scanning resolution are very important in order to obtain accurate information. The R-values for muscle area, circumference, long and short axes lengths, and direction ranged from 0.95 to 0.99, whereas those of the distance between any two muscle centers of gravity ranged from 0.96 to 0.99, respectively. For the cross section total area, lean, fat, and bone it ranged from 0.83 to 0.99. Excellent repeatability measurements were observed for muscle direction and distance between any two muscle centers of gravity. The results indicate that the Computer Image Analysis technique using a desk top computer for extracting information from carcass cross section is reliable and has high precision. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 8 : 1171-1176*)

Key Words : Computer Image Analysis, Desk Top Computer, Carcass Cross Section, Precision, Japanese Black Steers, Photoshop

INTRODUCTION

Estimation of the amount of edible meat, separable fat and bone in the carcass is of importance in progeny testing, studies on carcass evaluation and survey of consumer's choice for a certain portion of beef. Therefore researchers have been trying to establish a readily applicable and efficient method to estimate carcass composition.

Studies on an objective system of carcass estimation aim at the development of an automatic and non-invasive method. The objective automatic estimation of carcass composition has been investigated by several researchers (Berg et al., 1994; Horgan et al., 1995; Henkins et al., 1995; Lazzaroni et al., 1996; Hwang et al., 1997). The advantages of such a system are the possibility of higher accuracy, saving on working hours, objectivity and increased consistency. The technology to be applied for the estimation must be simple and easily used.

The application of Computer Image Analysis (CIA) technique to the estimation of carcass composition in beef cattle has been investigated (Wassenberg et al., 1986; Patterson, 1990; Anada et al., 1993; Patterson and Farid, 1994). Karnuah et al. (1994a, b, 1995, 1996) established and used the CIA technique to estimate the carcass composition of Japanese Black steers, Holstein steers and Crossbred (F_1) Japanese Black×Holstein using the Image Processing System (IPEX) of the Fujitsu Integrated Visual Information System (FIVIS). In order to devise a method that is more suitable for practical application, a new approach of CIA technique using a desk top computer to extract useful information from beef carcass cross sections is needed.

The objectives of this study were to establish the CIA technique using a desk top computer and to evaluate the precision of CIA information extracted by repeatability (R) and coefficient of variation (CV).

MATERIALS AND METHODS

Animals

Carcass data from 55 Japanese Black steers obtained from Chugoku National Agricultural Experiment Station, the Ministry of Agriculture, Forestry, and Fisheries were used.

Method of photographing the carcass cross section

After slaughter, the carcass was divided into right and left sides, and kept in a 0-2℃ refrigerator for one

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day. The left side of the cold carcass was cut precisely between the 6th and 7th ribs, the cut cross section was laid horizontally with all the outline and all the individual muscles clearly exposed; an individual identification number and measurement scale were assigned to each cross section, and pictures of the cross section were taken using negative color film. In order to provide maximum lighting for the photographs, two 100-200 W SFC reflectors were placed on each side of the cross section. After grading, the entire outline and individual muscles, bone and ligament areas of the cross section were traced by a qualified grader using transparent sheet and pencil, this information served as reference data for comparison and conformation with the photo image processing.

Procedure of CIA by desk top computer

The CIA procedure was conducted using a desk top computer (Macintosh-Apple Vision 1710 Display) connected to a scanner (Nikon Scantouch) and an image capture camera. Two software applications, Adobe Photoshop (3.0j) and Mac Scope (PPC/ver. 2.00) were used interchangeably. The flow chart of the CIA procedure by desk top computer is presented in figure 1.

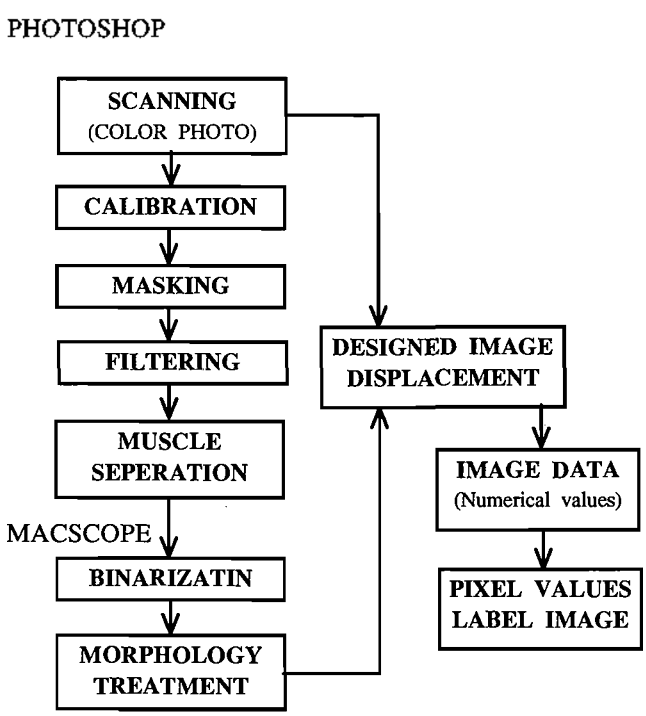

Figure 1. Flow chart of CIA Procedure by desk top computer

Scanning

A flatbed scanner, Nikon Coolscan, was used to digitize the color photo of the cross section directly to the Photoshop. When a visual image is digitized, it is transformed into digital signals so that it can be broken down into picture elements (pixels) and loaded into the computer for later processing. The cross section photo was scanned, digitized and processed by Photoshop as color (RGB) image. In order to ensure that the photos were digitized correctly and suitable for editing on desk top computer, the scanning resolution was set at 145 pixel per inch (ppi). The original photo of a cross section between the 6th and 7th ribs is shown in figure 2.

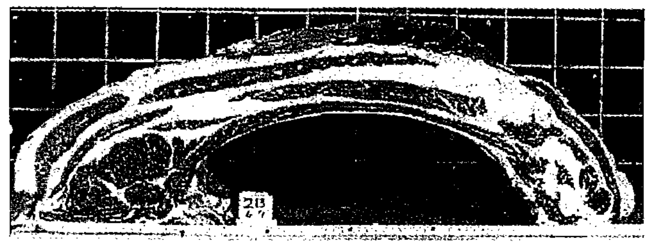

Figure 2. Original photo of the cross section cut between the 6th and 7th ribs

Calibration

Calibration values were selected using the measurement scale which is included in the photo of each cross section. A distance of 10 cm was sampled three times at different points of the image and averaged. The value measuring the number of pixels per every 10 cm of the image was used to convert the pixel values into numerical data. Each image has its own calibration value.

Masking

In order to extract from an image explicitly, the points that belong to the object has to be masked or selected in a special way. A mask allows an area of an image to be selected and protected so that it can be edited, painted, or filtered. This marking process is referred to as creating a "mask", congruent with the image. The Photoshop selection tool was used to select the area of the cross section necessary for further processing. After selection, the masked area was then saved in Photoshop.

Filtering

After masking, the saved image was then recalled for filtering. Filter is used to enhance an image and disguise its defects. A filter can turn soft, blurred contours into sharp crisp edges, or it can soften an image that has jagged or harsh edges. Filtering also removes dust and scratches in digitized images and helps to eliminate color bending (abrupt changes in color values) and noise (randomly colored pixels that appear in scanned images). Each Photoshop's filter produces a different effect. Many filters achieve their effect by first sampling individual pixels or groups of pixels to define areas that display the greatest difference in color or brightness.

In this process, the blur and sharpen filters were applied depending on the image. The blur filter creates a light blurring effect that can be used to decrease contrast and eliminate noise in the color transitions. The sharpen filter sharpens the image and edges by increasing the contrast between neighboring pixels. Also the image/adjust tool was used to adjust brightness and contrast of the image, because some images may appear dark after scanning causing them to lose contrast.

Muscle separation

Muscles and bones appearing in the carcass cross section were individually selected and separated using Photoshop separation tool. Boundary lines were drawn along the edges and between the muscles for proper separation and identification. Muscle separation enables the computer to identify the boundary line between muscles and between muscle and fat. After muscle separation, the image was transferred to Mac Scope application for further processing.

Gray scale and binarization

In the Mac Scope application, the image is processed as a gray scale image. Gray produces transitional colors through 256 shades from black and white. It is a single channel image consisting of up to 256 levels of gray, with 8 bits of color information per pixel. The gray color image is then transformed into a binary image. In the binarization process, the original pixel value with 256 levels (0-256), is linearly transformed into two threshold levels, 0 and 1. The binary value of 1' correspond to Black, and the binary value 0' to White. After binarization, various morphological treatments are applied to the image such as the deletion of unwanted pixels, closing of spaces created by intramuscular fat within the muscle, and the modified images then saved as binarized data.

Designed image displacement

The original digitized color image is recalled on the screen and overlapped with the computer designed image of the cross section for comparison, to make sure that the two images are exactly the same. The designed image of the cross section is that produced by image analysis after scanning, digitization, masking, muscle separation and binarization. The designed and label image is shown in figure 3.

Label image

From the binarized data, each muscle of the cut surface area and other selected areas were distinguished by using different color labels and stored as label images. Pixels having the same values were connected to constitute a lump, called a coupling element. Each coupling element was assigned a different color (Harder, 1995). The locations of the muscles in the cross section are shown in the reports of Karnuah et al. (1994a, b).

Pixel values

Bound connectivity between pixels is an important concept used to establish boundaries of the objects and components of regions within the image. To establish the boundaries, 4-connectivity was applied, and the pixel values were automatically assigned to each muscle, fat, and bone areas, and other selected areas. In order to convert the pixel vales into numerical data, the calibration values were used.

Information extracted from the cross section

As the information extracted was transformed from image data into numerical data, the image information can be treated as figure. The information extracted included the following: 1) individual muscle area, 2) muscle circumference, 3) long and short axes lengths, 4) muscle direction of long axis, 5) distance between any two muscle centers of gravity, 6) cross section total area, 7) cross section total lean area, 8) cross section total fat area, and 9) cross section total bone area.

Area (cm^2) and circumference (cm) measure the size of the muscles, as it relates to the number of pixels contained within its boundary. The principle axis (long and short axes) length measures the shape and spread of the muscle. Muscle direction of the long axis measures the degree of the angle between the horizontal axis and the long axis length of that particular muscle. This is referred to as the precision of orientation (Gonzalez and Winz, 1987). Muscle orientation plays an important role in indicating the muscle distribution pattern in the outer surface of the

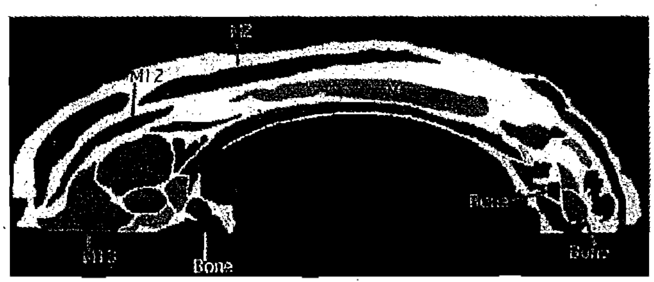

Figure 3. Designed and label image (M2: *M. latissiums dorsi*, M3: *M. pectoralis profundus*, M4: *M. serratus ventralis thoracis*, M7: *M. trapezius pars thoracis*, M8: *M. intercostalis*, M11: *M. longissiums thoracis*, M12: *M. rhomboidues thoracis*, M13: *Mm. spinalis dorsi & cevic*)

cross section. Distance between any two muscle centers of gravity determines how far or near the muscles are to one another. This is important in estimating the amount of intermuscular fat deposited between two adjacent muscles, and also gives information on the size of the muscles. This is because in order to determine the center of gravity of a muscle, the size (width and length) of the muscle is taken into consideration (Gonzalez and Winz, 1987).

The muscles examined were: *M. latissiums dorsi* (M2), *M. pectoralis profundus* (M3), *M. serratus ventralis thoracis* (M4) *M. trapezius pars thoracis* (M7), *M. intercostalis* (M8), *M. longissiums thoracis* (M11), *M. rhomboidues thoracis* (M12), and *M. semipinalis capitis* (M13).

Statistical analysis

The image analysis information was extracted repeatedly considering all the image analysis procedures (figure 1). Data were treated with the Statistical Analysis System (SAS, 1985) using GLM procedure. The model equation used for the analysis of variance was:

$$Y_{ij} = \mu + \beta_i + e_{ij},$$

where Y_{ij}= jth measurement in the ith animal; μ = overall mean; β_i = effect of the ith animal; e_{ij} = error of jth measurement in the ith animal.

Repeatability (R) value and coefficient of variation (CV) for error variance were calculated according to Gomez and Gomez (1981). The equations used are as follows:

Repeatability (R) = $V_B/(V_E+V_B)$

Coefficient of variation (CV)=$(s/\overline{X})\times 100$

where V_B=variance between animals; V_E=error variance within an animal, and s= standard deviation, $\overline{X}$=sample means.

The repeatability is an estimate of stability of measurements within an animal. On the other hand, the coefficient of variance is used as a measure of precision of the measurement.

RESULTS AND DISCUSSION

Ensuring that the cross section photos are digitized correctly is important for the success of CIA technique by desk top computer. If the digitization process is not conducted properly, image quality will likely be unacceptable and colors may be flawed. Before scanning, the dimensions of photo/image should be considered and the correct scanning resolution should be selected. Like monitor resolution, scanning resolution is measured in pixels per inch (ppi). The more pixels in an image means it contains more information. Also the more pixels that can be packed in an image, the sharper the image. Low resolution will result in jagged pixels in the image thereby reducing the number of pixels or information. On the other hand, high resolution will eventually make the image appears flat and file size will increase making it unmanageable on a desk top computer.

In this research, several resolution values were tested, i.e., 140, 145, 150, and 200. It was observed that the pixel values changed along with different resolution values. Using the data obtained in the previous report of Karnuah et al. (1994a, b) by FIVIS as a reference, the resolution at 145 gave the close results. In using the CIA technique by desk top computer to extract information from the carcass cross section, it is most important to consider the image size and scanning resolution. With desk top computer different pixel values will be obtained with different image size and scanning resolution.

Using the CIA technique by desk top computer with Mac Scope application, the obtained pixel values can be easily converted into numerical values through the calibration values, whereas with the FIVIS, a special FORTRAN program had to be written. Also muscle separation can easily be done by desk top computer with the Photoshop application using the Photoshop drawing and separation tool, whereas with FIVIS, stylus pen was the only option.

R-values and CV of various muscle areas, circumference lengths, long and short axes lengths, and muscle direction of long axis length are shown in table 1. The R-values observed ranged from 0.95 to 0.99 for all the measurements. These results are comparable with those of Anada et al. (1992) and Cross et al. (1983), but higher than those of Komlosi and Dewi (1994). On the other hand, the CV for measurement errors were low, ranging from 0.01 to 2.9.

Table 2 presents the R-values and CV for distance between any two muscle centers of gravity. The R-values were very high ranging from 0.96 to 0.99, whereas those of the CV ranged from 0.2 to 2.5. Patterson and Farid (1994) reported R-values ranging from 0.80 to 0.99 using Video Image Analysis (VIA) system.

Table 3 shows the R-values and CV for cross section total area, lean, fat, and bone. Very high R-values and low CV were obtained except for cross section total bone. The R-values ranged from 0.83 to 0.99, whereas those of the CV ranged from 0.8 to 7.7. The R-values obtained are higher compared with those of Cross et al. (1983), who reported intraclass correlations of 0.68 to 0.98 by VIA on beef carcass. The R-value of cross section total bone decreased, with high CV. This could be due to the appearance of

Table 1. Repeatability (R) values and coefficients of variation (CV) for muscle area, circumference length, long axis length, short axis length, and direction measured on eight muscles by image analyzer with desk top computer

	Area		Circumference length		Long axis length		Short axis length		Direction	
Muscle	R	CV (%)	R	CV(%)	R	CV(%)	R	CV(%)	R	CV(%)
M 2[a]	0.98	2.2	0.98	1.0	0.99	0.5	0.98	1.9	0.99	0.1
M 3	0.99	2.4	0.99	1.3	0.99	0.5	0.99	2.2	0.99	0.3
M 4	0.98	2.6	0.95	2.4	0.99	0.8	0.99	2.1	0.99	0.4
M 7	0.99	2.4	0.97	2.3	0.98	1.4	0.99	2.3	0.99	0.2
M 8	0.98	2.2	0.99	0.9	0.99	0.7	0.95	2.5	0.99	0.2
M 11	0.99	1.3	0.99	1.5	0.99	1.3	0.99	1.3	0.99	0.9
M 12	0.99	2.4	0.99	1.9	0.99	0.7	0.97	1.9	0.99	0.1
M 13	0.97	2.8	0.96	2.9	0.98	1.5	0.97	2.4	0.99	0.5

[a] See text.

Table 2. Repeatability (R) values and coefficients of variation (CV) for distance between any two muscle centers of gravity measured by image analyzer with desk top computer

Distance between muscles	R	CV (%)
M 2 - M 3[a]	0.99	0.2
M 2 - M 4	0.99	0.8
M 2 - M 7	0.99	0.4
M 3 - M 4	0.99	0.3
M 3 - M 8	0.99	0.6
M 4 - M 8	0.99	0.1
M 4 - M 11	0.99	0.5
M 4 - M 12	0.99	0.4
M 7 - M 12	0.99	0.3
M 7 - M 13	0.96	2.8
M 8 - M 11	0.99	0.5
M 8 - M 12	0.99	0.6
M 11 - M 12	0.99	2.5
M 11 - M 13	0.99	0.9
M 12 - M 13	0.99	2.3

[a] See text.

Table 3. Repeatability (R) values and coefficients of variation (CV) for cross section total lean, fat, and bone areas measured by image analyzer with desk top computer

Cross section area (cm^2)	R	CV (%)
Total	0.99	0.8
Total lean	0.95	2.7
Total fat	0.96	2.4
Total bone	0.83	7.7

bone area in the 6th and 7th ribs cross section area, which is small and more difficult to identify.

The results obtained in this study from the repeatability measurements of the various information extracted by the CIA technique with a desk top computer are very the similar to those of Karnuah et al. (1994a, b) obtained by FIVIS, and of Cross et al. (1984) by VIA. The R-value of total bone (0.83) is lower compared to 0.99 by Karnuah et al. (1994a, b). In the 6th and 7th ribs cross section of Japanese Black, the appearance of bone is much smaller and difficult to recognize. This might have also contributed to the difference in the R-values.

Higher repeatability is obtained when anatomical reference points can be clearly identified in image views. It is also necessary that the information extracted is selected on reliability of the measurement and biological importance. Muscle direction of long axis length and distance between any two muscle centers of gravity show the highest R-values among all the measurements. From this point of view, muscle direction and gravity distance are important because they include information on muscle distribution pattern and inter-muscular fat between adjacent muscles and also the muscle size.

These results indicate that the CIA technique by desk top computer is reliable, and can be used to extract information from the carcass cross section with high precision. This means that the CIA technique can be applied to a more practical situation, e.g., carcass evaluation at the slaughter house.

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