# 豚おける枝肉形質の超音波測定値についてのオペレーター,解析者および機械の効果

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# The Effects of Operator, Interpreter and Machine on Ultrasonic Estimates of Carcass Traits in Pigs

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Two sets of experiments were conducted to evaluate the effects of operator, interpreter and machine on ultrasonic estimates of carcass traits. Experiment I was for interpreter and machine effects that utilized 67 head of Landrace pigs at 90 kg body weight while experiment II was for operator effects with 28 head of pigs of the same breed scanned at 40, 60 and 90 kg body weights. Scanning positions A and B were taken between the $5^{th}$ and $6^{th}$ ribs and C and D between the $12^{th}$ and $13^{th}$ ribs. Ultrasonic carcass traits were estimated of the rib eye area (REA) at positions A and C, fat thickness (FT) at positions A, B and C, rib thickness (RT) at positions B and D, and total thickness (TT) at position D. Scanning machine used was a real-time ultrasound (RTU) for the interpreter and the operator effects, while RTU and a mechanical scanning scope (MSS) were used to evaluate the effects of machine. Mean differences between two interpreters were small with significant correlation coefficients of 0.90, 0.91, 0.95, 0.78 and 0.98 for A-REA, C-REA, A-FT, C-FT and B-RT, respectively. Mean differences between RTU estimates with actual C-REA was small with correlation coefficient of 0.95 while little bit bigger for MSS with correlation coefficients of 0.93. Contrary to this, mean difference between RTU estimates with actual C-FT was big with correlation coefficient of 0.91 while small for MSS with the correlation coefficient of 0.89. Mean differences between RTU and MSS were small with correlation coefficients of 0.90 and 0.84 for C-REA and C-FT, respectively. On the other hand, mean differences for ultrasonic estimates of carcass traits between two operators were small with correlation coefficients that ranged from 0.78 to 0.98 at 40, 60 and 90 kg body weights.

**Key words**: Operator, Interpreter, Ultrasound, Carcass Traits

## Introduction

The ability to estimate accurately carcass characteristics of live animal is important in economic standpoint of animal production. An objective appraisal system is needed in order to eliminate the variation in evaluation if live animal is to be given emphasis. Ultrasonic techniques have been introduced with the methods used and the accuracy of estimating the rib eye area and fat thickness.

Ultrasonic research has been an area of interest up to the present times. Most of the studies have had the objective of trying to determine the accuracy of various equipments and techniques for measuring the rib eye area and fat thickness. Numerous ultrasound instruments are currently avail-

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able for animal research, but there seem to be considerable variations among the ultrasound instruments in the efficacy of estimating body composition.

Ultrasonic techniques have been used to evaluate the carcass composition in live animals since 1950's. During this time, simple A-mode pulse-echo machines have been largely used and then later replaced by more sophisticated B-mode and real-time machines, which resulted in an improvement in the precision of predicting carcass traits. Researchers have reported discrepancies in the accuracy of measurements of ultrasound in predicting carcass traits in live animals[11]. Experimental results from the literature are reviewed[12] and recommendations are made on scanning procedures, and assessing the results of trials. Some researchers have found that ultrasound measurements of physical dimensions and subsequent prediction of carcass composition to be quite accurate[1, 5, 7, 17, 24], whereas others[2, 14, 16, 18, 23], have not. They identified that potential differences due to instruments, type of animals, operators, technicians, interpreter experience, hide thickness, haircoat length, weight, and fat level are possible contributors to these varied results. Previous studies[9, 10, 15] suggest that ultrasonic measurements of fat thickness are accurate in determining carcass fat thickness, but that rib eye area estimates are inconsistent and warrant further investigation. Some of the researches have also shown that accuracy is highly dependent on the technician and his level of experience[13]. Differences in operators and machines have been suspected to alter the accuracy and repeatability of ultrasound measurements[13, 19]. There is considerable variation in the ability of technicians to produce repeatable results with the ultrasonic equipment[3, 20, 21]. The objective of this study was to evaluate the effect of operator, interpreter and machine on ultrasonic estimates of carcass traits in pigs.

## Materials and methods

Two sets of experiments were done in this study. First set of experiment utilized 67 head of Landrace pigs. Each animal was scanned at 90 kg body weight prior to slaughter using two machines and scan images from real-time ultrasound (RTU) was interpreted by two technicians. Second set of experiment utilized 28 head (♂ = 14 ; ♀ = 14) of pigs of the same breed in the first experiment ultrasonically scanned at 40, 60 and 90 kg body weights. Each animal was scanned by two operators.

Scanning was done on the left side of the body. Scanning positions were A and B taken between the $5^{th}$ and $6^{th}$ ribs and C and D between the $12^{th}$ and $13^{th}$ ribs. Positions A and C were scanned at the midback at about 5 cm from the midline with B below A and D below C. Carcass traits estimated by two interpreters were rib eye area (REA) and fat thickness (FT) at positions A and C, and rib thickness (RT) at position B while REA and FT estimates with actual carcass measurements at positions A and C were used to evaluate the accuracy of two machines. On the other hand, the carcass traits estimated by two operators were REA at positions A and C, FT and total thickness (TT) at positions B and RT at position D. The combination of position and trait was consider as one trait. For example, REA and FT on position A were defined as A-REA and A-FT, respectively.

The scanning machine used was a real-time ultrasonic (RTU) scanner (Super-eye MEAT, FHK Co. Ltd.,) with a B-mode electronic linear probe (27 mm × 147 mm, multi-transducer, 2MHz) and a mechanical scanning scope (MSS) machine (20 mm × 30 mm, single transducer, 1MHz) for evaluating the effects of two machines. Scanning images from RTU were used to evaluate the effect of two interpreters and for the effects of two operators. A scan-

Table 1. Ultrasonic estimates of carcass traits by two interpreters

| Interpreter | A-REA | C-REA | A-FT | C-FT | B-RT |
|---|---|---|---|---|---|
| I | 24.9±2.5 | 38.0±3.3 | 15.0±2.1 | 17.2±2.8 | 39.5±4.9 |
| II | 24.7±2.7 | 38.4±3.4 | 15.5±2.3 | 16.5±2.4 | 39.7±4.9 |

A, B, C = Scanning positions ; REA = Rib eye area ($cm^2$) ; FT = Fat thickness (mm) ; RT = Rib thickness (mm)

Table 2. Mean differences and correlation coefficients of ultrasonic estimates of carcass traits between two interpreters

| Variable | A-REA | C-REA | A-FT | C-FT | B-RT |
|---|---|---|---|---|---|
| Mean diff. | 0.20±1.2 | -0.40±1.4 | -0.50±0.7 | 0.70±1.8 | -0.20±0.9 |
| Cor. coeff. | 0.90** | 0.91** | 0.95** | 0.78** | 0.98** |

** : P < 0.01. Abbreviations of ultrasonic estimates of carcass traits and scanning positions are same in Table 1.
Mean diff. = Σ (interpreter I − Interpreter II) ／number of animals.

ning image was obtained by the use of a video-copy machine (Aloka Co. Ltd., SSZ-300S) for RTU while a video-tape camera for MSS. Each scan image was interpreted on a tracing paper and measured by means of a digitizer-computing image system.

Data from two sets of experiments were analyzed using the correlation analysis. Mean difference, standard error of prediction and minimum significant difference were also used in the analysis to explain the accuracy of data as described in the previous report[6].

## Results and Discussion

Ultrasonic estimates of carcass traits of the pigs by two interpreters are presented in Table 1. Results indicated that ultrasonic estimates interpreted by two interpreters were nearly equal to each other. However, mean differences between two interpreters as indicated in Table 2 were 0.20, -0.40, -0.50, 0.70 and -0.20 with correlation coefficients of 0.90, 0.91, 0.95, 0.78 and 0.98 for A-REA, C-REA, A-FT, C-FT and B-RT, respectively. The differences on ultrasonic estimates between two interpreters were relatively small which probably would account on the interpreters level of experience that they obtained almost similar results. In this experiment, both interpreters were equally experienced in scan image interpretaion. The scan image obtained from pig with the ultrasonic machine used in this study was clear enough to identify fat and muscle boundaries. However, this result is on the contrary of other research findings. SIMM[22] cited in his review paper that most workers have reported important differences between two interpreters in cattle. GILLIS *el al.*[8] found that interpreter experience in scan image interpretation was especially important and that correlation between ultrasonic measurement with actual carcass measurement were high in more experience than less experience interpreters. However, in this experiment both interpreters were already experienced in image interpretation that is why the differences obtained were small. Also, scan image of fat and muscle would be probably more easier to interprete in pig than in cattle. The mean difference in C-FT (0.70) was

Table 3. Accuracy of two ultrasonic estimates of carcass traits of pigs scanned using two ultrasonic machines

| Variable | C-REA ($cm^2$) | | C-FT (mm) | | A-REA ($cm^2$) |
|---|---|---|---|---|---|
| | RTU | MSS | RTU | MSS | RTU |
| Actual carcass measurements | | | | | |
| Mean ± S. D. | 38.3±3.3 | | 19.6±3.1 | | 24.7±2.6 |
| Measurements with ultrasonic machine | | | | | |
| Mean ± S. D. | 38.0±3.3 | 37.2±2.9 | 17.2±2.8 | 18.7±3.0 | 24.9±2.5 |
| Mean diff. | 0.3±1.1 | 1.1±1.2 | 2.4±1.3 | 0.9±1.4 | -0.2±1.0 |
| Cor. coeff. | 0.95** | 0.93** | 0.91** | 0.89** | 0.93** |
| R. S. D. | 1.07 | 1.21 | 1.31 | 1.43 | 0.93 |
| S. E. of pred. | 1.11 | 1.66 | 2.71 | 1.71 | 0.98 |
| Min. sig. diff. | 2.58 | 3.86 | 6.32 | 3.97 | 2.28 |

** : $P < 0.01$ ; RTU = Real-time ultrasound ; MSS = Mechanical scanning scope. Abbreviations of traits are same in Table 1.

Mean diff. = Σ (Actual carcass measurement - Ultrasonic estimate) / number of animals.

$$\text{S. E. of pred.} = \sqrt{\frac{\Sigma D^2}{n-1}}$$

Minimum significant difference (Min. sig. diff.) $= 1.645 \times$ s. e. of prediction $\times \sqrt{2}$

higher and correlation coefficient lower than any other traits measured. This probably would account on the error between two interpreters in identifying the fat layer on this position. Moreover, the correlation coefficients which was lower than the other ultrasonic estimates of carcass traits obtained in this experiment would be on the differences between the two interpreters which are likely to be the same. HOUGHTON and TURLINGTON [12] reported that sample population variations influence correlation coefficients and that larger than normal variation will produce high correlation coefficients, whereas similar sample population will result in much lower correlation coefficients.

The accuracy of the RTU and MSS machines on ultrasonic estimates of carcass traits are presented in Table 3. The accuracy of two ultrasonic machines was checked on ultrasonic estimates of A-REA and C-FT. RTU machine was further checked with actual measurement on ultrasonic estimate of A-REA. Ultrasonic estimates of C-REA by RTU was slightly lower than the actual carcass measurements with the mean difference of 0.3 $cm^2$. However, the relationships between actual carcass measurement and ultrasonic estimate of C-REA was very high ($r = 0.95$). On the other hand, ultrasonic estimates of C-REA by MSS was much lower than the actual carcass measurement with the mean difference of 1.1 $cm^2$. Though, correlation coefficient between actual carcass measurement and ultrasonic estimates of C-REA by MSS was also high ($r = 0.93$). C-FT by RTU estimates (17.2 mm) was lower than that of the actual carcass measurements (19.6 mm). Similar pattern with low estimates was also obtained by MSS (18.7 mm). However, the mean difference between the actual carcass measurement and the ultrasonic estimates was smaller by MSS (0.9 mm) than by RTU estimates (2.4 mm), indicating closer relationships of MSS with the actual carcass measurement. Correlation coefficients between actual carcass measurements and ultrasonic estimates of C-FT was 0.91 and 0.89 for RTU and MSS, respectively. Although, the correlation coefficient of C-FT by MSS was slightly lower than by RTU estimates despite the small mean difference obtained by MSS, the s. e. of prediction and minimum significant differences were lower in MSS than that of RTU estimates. It seemed to appear that RTU estimate is more closer with the actual measurement for C-REA and MSS for C-FT. The small mean differences on ultrasonic estimates with the actual carcass measurements of these two machines would be attributed to the differences of transducer or frequency of probe used or the machine itself such that error on interpretation of scan image cannot be avoided. MSS has a scan image with dots, rough picture and there is no distinct boundaries of fat and muscle tissues while RTU has smooth scan image with shape like the actual image, clear boundaries of fat and muscle tissues. These machine differences on pictures would lead to some error or differences on interpretation of scan image especially during tracing for measuring the thickness of fat and area of muscle.

Ultrasonic estimates of A-REA by RTU estimates was slightly higher than the actual carcass measurements. Mean difference was -0.2 $cm^2$ with the correlation coefficient of 0.93. MSS was not used to detect this trait.

Mean differences and correlation coefficients between two ultrasonic estimates of carcass traits are provided in Table 4. Ultrasonic estimates of C-REA were $38.0 \pm 3.3$ $cm^2$ and $37.2 \pm 2.9$ $cm^2$ by RTU and MSS estimates, respectively with the mean difference of 0.8 $cm^2$. The correlation coefficient for C-REA between the two machines was 0.90. On the other hand, ultrasonic estimates of C-FT were $17.2 \pm 2.8$ mm and $18.7 \pm 3.0$ mm by RTU and MSS estimates, respectively with the mean difference of -1.4 mm. The correlation coefficient for C-FT between two machines was 0.84. Results indicated that both machines are capable of detecting the rib eye area and fat thickness.

Ultrasonic estimates of carcass traits at 40, 60 and 90 kg body weights by two operators are presented in Table 5. Mean differences of ultrasonic estimates of carcass traits between two operators shown in Table 6 were small and range from -0.014 to 0.132 $cm^2$ for A-REA, 0.014 to 0.146 $cm^2$ for C-REA, -0.011 to 0.175 mm for B-FT, -0.200 to 0.464 mm for B-TT and -0.311 to 0.021 mm for D-RT at 40, 60 and 90 kg body weights. Correlation coefficients between two operators in all ultrasonic estimates of carcass trait at 40, 60 and 90 kg body weights were all high that ranges from 0.72 to 0.98. This result is in agreement of the result obtained by CAMPBELL and HERVE [4] who found no significant differences between ultrasonic measurements made by two operators. TULLOH *et al.*[25] formed the same conclu-

Table 4. Mean differences and correlation coefficients between two ultrasonic estimates of carcass traits

| Variable | C-REA ($cm^2$) | | C-FT (mm) | |
|---|---|---|---|---|
| | RTU | MSS | RTU | MSS |
| Mean ± S. D. | 38.0±3.3 | 37.2±2.9 | 17.2±2.8 | 18.7±3.0 |
| Mean diff. | 0.8±1.4 | | -1.4±1.6 | |
| Cor. coeff. | 0.90** | | 0.84** | |

** : $P < 0.01$. RTU = Real-time ultrasound ; MSS = Mechanical scanning scope. Abbreviations of traits are same in Table 1.
Mean diff. = Σ (RTU - MSS) / number of animals.

Table 5. Ultrasonic estimates of carcass traits by two operators

| Operator | BW | A-REA | C-REA | B-FT | B-TT | D-RT |
|---|---|---|---|---|---|---|
| I | 40 | 11.5±1.2 | 16.6±1.8 | 6.2±1.0 | 25.1±2.5 | 11.0±1.2 |
| | 60 | 17.1±1.9 | 24.2±2.8 | 7.3±1.1 | 30.5±2.6 | 13.9±1.3 |
| | 90 | 25.2±2.9 | 35.0±4.3 | 9.7±1.3 | 42.9±4.7 | 19.7±1.8 |
| II | 40 | 11.5±1.2 | 16.6±1.8 | 6.2±1.0 | 25.3±2.6 | 11.4±1.3 |
| | 60 | 16.9±1.8 | 24.2±2.7 | 7.3±1.0 | 30.9±2.6 | 14.2±1.1 |
| | 90 | 25.2±2.8 | 34.9±4.1 | 9.6±1.2 | 42.4±4.1 | 19.6±1.7 |

A, B, C, D = Scanning positions ; BW = Body weight (kg) ; REA = rib eye area ($cm^2$) ; FT = Fat thickness (mm) ; TT = Total thickness (mm) ; RT = Rib thickness (mm).

Table 6. Mean differences and correlation coefficients of ultrasonic estimates of carcass traits between two operators

| Variable | BW | A-REA | C-REA | B-FT | B-TT | D-RT |
|---|---|---|---|---|---|---|
| Mean diff. | 40 | -0.01±0.5 | 0.01±0.5 | -0.01±0.5 | -0.20±1.3 | -0.40±1.0 |
| | 60 | 0.13±0.6 | 0.09±0.9 | 0.01±0.3 | -0.46±1.8 | -0.31±0.6 |
| | 90 | 0.00±0.9 | 0.15±0.8 | 0.18±0.4 | 0.46±1.6 | 0.02±0.7 |
| Cor. coeff. | 40 | 0.91** | 0.96** | 0.85** | 0.88** | 0.72** |
| | 60 | 0.94** | 0.95** | 0.96** | 0.80** | 0.91** |
| | 90 | 0.95** | 0.98** | 0.97** | 0.95** | 0.93** |

** : $P < 0.01$. Footnote on abbreviations of traits and scanning positions are same in Table 5.
Mean diff. = Σ (Operator I - Operator II) ／number of animals.

sion, and suggested that provided operators were trained in the use of machine and anatomy of the animal, comparisons of a group of animals need not to be restricted to one operator. WALLACE *et al.*[26] also found no significant difference between operators.

## Implications

The results of this research suggested that ultrasound is a valid tool for measuring carcass traits in animals. However, the ultrasonic estimates of carcass traits between interpreters, operators and ultrasonic instruments showed small differences. Differences between operators were generally smaller than differences between interpreters. Although the differences between interpreters, operators and machines are relatively small, under field condition wherein large number of animals need to be scanned, it is necessary that all ultrasound operators, interpreters undergo training to ensure good ultrasonic estimates of carcass traits. Results also indicate good estimation with machines that allow complete imaging of the important muscle and fat boundaries. Ultrasound as a tool for genetic improvement and good carcass prediction is dependent on the use of trained technicians and properly calibrated ultrasonic machines.

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# 豚おける枝肉形質の超音波測定値についてのオペレーター，解析者および機械の効果

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## 要約

豚枝肉形質の超音波測定値へのオペレーター，解析者および機械の効果を評価するために2つの実験を行った．実験Ⅰは体重90kg時のランドレース種67頭の超音波測定値を用いて解析者および機械の効果についての検討を行い，実験Ⅱではランドレース種28頭を体重40，60および90kg時に経時的に測定し，オペレーターの効果について検討を行った．超音波測定は第5－6胸椎部（AおよびB）および第12－13胸椎部（CおよびD）について行った．超音波測定形質はAおよびC部位におけるロース芯面積（REA），A，BおよびC部位における皮下脂肪厚（FT），BおよびD部位におけるバラの厚さ（RT）およびD部位における全体厚（TT）である．オペレーターおよび解析者の効果の検討については電子スキャン装置（RTU）を用い，機械の効果の検討にはRTUおよびアークスキャン装置（MSS）を用いた．A-REA，C-REA，A-FT，C-FTおよびB-RTにおける解析者間の差の平均は，それぞれ0.20cm$^2$，-0.40cm$^2$，-0.50mm，0.70mmおよび-0.20mmであり，相関係数はそれぞれ0.90，0.91，0.95，0.78および0.98で有意性が認められた．C-REA実測値とRTU測定値との差の平均および相関係数はそれぞれ0.3cm$^2$および0.93であり，MSSとの差の平均および相関係数は1.1cm$^2$および0.93であった．C-FT実測値とRTU測定値との差の平均および相関係数はそれぞれ2.4mmおよび0.91であり，MSSとの差の平均および相関係数は0.9mmおよび0.89であった．また，C-REAおよびC-FTにおけるRTUおよびMSS測定値の差の平均はそれぞれ0.8cm$^2$および-1.4mmであり，相関係数は0.90および0.84であった．一方，体重40，60および90kg時における枝肉形質の超音波測定値のオペレーター間の差は小さく，また相関係数の範囲は0.78から0.98であった．

**キーワード：** オペレーター，解析者，超音波，枝肉

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