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Ultrasound Measurement of Backfat Thickness and Longissimus Muscle Area in Live Swine: Effects of Equipment, Personnel and Pigs Pose

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Abstract: Ultrasound measure is an important tool to evaluate carcass merit in live swine and the accuracy of ultrasonic measurement directly related to the breeding process. Here, researchers studied the effects of machine, posture and technician factors on the accuracy of ultrasonic measurement in live swine. The results indicated that the accuracy of A-mode ultrasonic machine measurement was lower than B-mode ultrasonic machine measurement and the accuracy of B-mode ultrasonic machine with equipped 3.5 MHz linear array probe performed the highest accuracy. Measured through the ultrasonic machine back fat thickness obtained from both the posture of bowing back ($p<0.01$) and standing posture with mouth contacting with the ground ($p<0.05$) were statistically significant different from the real carcass backfat thickness. Obtained from the posture of pigs were standing naturally both backfat thickness and logissimus muscle area were most approximated to the true value. During the operation of ultrasonic machine, the value of backfat thickness recognised by unexperienced technicians was statistically significantly different ($p<0.01$) from the true value. Thus in the process of measure both back fat thickness and logissimus muscle area through ultrasonic machine, the types of machine, the posture of pig standing and the skill level of technicians were validated to influence the obtaining of true value. In conclusion, the results indicated that the accuracy of ultrasonic measurement can be improved by suitable machines and probes, obtain picture while pig are standing naturally and skilled technicians.

Key words: Ultrasonic measurement, *in vivo* measurement, backfat thickness, longissimus muscle area, accuracy, swine

INTRODUCTION

Ultrasonic measurement is usually used as an important means for the live pig back fat and eye muscle area measurement. In the 1960's, researchers began to use ultrasonic to measure live animal back fat thickness and eye muscle area (Temple *et al*., 1956 and Stouffer *et al*., 1959). Ultrasonic live measurement of back fat and eye muscle area are used by many countries as a basis of selective breeding research and used for pig carcass traits and some genetic improvement of meat quality traits (Silva and Cadavez, 2012). The pig back fat thickness and eye muscle area is directly related to the pig lean meat rate (De Koning *et al*., 1999), it is two important indicators of pig genetic breeding and performance testing so it is deeply concerned (Elzo *et al*., 2013). The living measurement accuracy is of great significance (Williams, 2002; Baas, 2005; Leeds *et al*., 2008; Esquivelzeta *et al*., 2012) and it is also the difficulty place and attention place.

Ultrasonic measurement of pig back fat thickness and the accuracy of the eye muscle area is affected by various factors. Hassen *et al*. (1998), Sather *et al*. (1986), Herring *et al*. (1994) and Bergen *et al*. (1996) believed that the technical staff through training to improve the measuring accuracy of back fat and eye muscle area. Sather *et al*. (1986), Herring *et al*. (1994) and Charagu *et al*. (2000) thought that using different instruments to do the living measure have significant difference in the accuracy. Pomar and Marcoux (2005) and Silva *et al*. (2006) compare the accuracy of the four types of probe in measurement, according to the body measurement there is a significant difference, respectively between the different probe. Smith *et al*. (1992), Moeller *et al*. (1998) and Stanford *et al*. (2001) thought that both breeds and gender will affect the accuracy of living measurements. Yokoo *et al*. (2008) thought that the changes in the environment can affect the accuracy of ultrasonic living measurement.

Most of the existing research focused on the factors such as personnel, instrument, varieties of ultrasonic living influence on the accuracy of the measurement, the recognition of different testing personnel in the ultrasound images and equipment factors of measurement

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accuracy is not perfect, especially the alive measurement of the different pig positions, the relative report has not seen. In view of this this study analyzes the measure the factors of personnel, instrument and the posture of pig to influence ultrasonic measure accuracy of the back fat and eye muscle area and expect to provide reference for the ultrasonic accurately living measure in the breeding research improve the efficiency of genetic evaluation of breeding.

MATERIALS AND METHODS

Testing personnel: Choose five technical personnel. Among them, 2 technical personnel have swine performance measurement member qualification certificate, have >10 years living ultrasonic measurement experience and their numbers is 1 and 2, respectively the technologist with 7 year's experience numbered 3, the technologist with 1 year's experience numbered 4 and the novice numbered 5.

Determining instrument: The test choose one A ultrasound and four B ultrasound instrument. Among these, A ultrasound is produced by LEAN-METER (Renco, America). B ultrasound is produced by AQUILA VET (Pie, Netherlands, 3.5 MHz linear array AS 30C/180 mm), SASET (SASET, China Chengdu, 5 MHz 128 element electronic scanning probe iPagoP20), CX-500 (Sonic, China Mianyang, 3.5 MHz 96 element electronic scanning probe) that RH2008 V (Haorunqi, China Zhengzhou, probe S2/3.5 MHz waterproof mechanical fan brush).

Experimental treatment: Factors for measuring instruments: select 6 (100±1) kg healthy pigs, three are DLY (Duroc x Landrace x Yorkshire) and three LR (Landrace x Rongchang pig). The first technical personnel use 5 instrument to detect pig's left and right shoulder blade trailing edge, the last 3-4 ribs, the last rib, lumbar shoulder junction, all these 8 position, back fat which is 5 cm to the dorsal line and take marking points in the measurement point and record the pig's ear number and back fat thickness. After 24 h empty stomach researchers kill the pig and measure the back fat thickness which is marked by the vernier caliper.

For pig posture factors: The test chose 4 common posture and position *in vivo* detection; natural stand up, stand up and mouth touch the ground, prone and bow back (Fig. 1). The number four detecting people use AQUILA VET instrument to detect 33 (100±1) kg healthy pigs (DLR Duroc x Landrace x Rongchang pig) detect the last 3-4 ribs near the middle of the back's back-fat thickness and eye muscle area of the four posture and marking at the detecting point. Kill the pig after 24 h empty stomach using the vernier caliper to detect the gauge point's back-fat thickness, eye muscle width and height. Using oil absorption study cling against the eye cross muscle-sections, draw a line along the eye muscle contour with oily pen. Then put the paper on plane table, put a ruler on it, take a picture with 50 mm standard lens about 0.5 m away from the horizontal position. At last, using IPP 6.0 (Media Cybernetics, America) Software to identify eye muscle area.

Factors for the determination of personnel: From the number 1 people's pose test, researchers select 31 natural standing position to save clearer B ultrasound live measuring image. The 5 technicist using IPP 6.0 Software to recognize the imagine's thickness of back fat and the eye muscle area and record the measurement data.

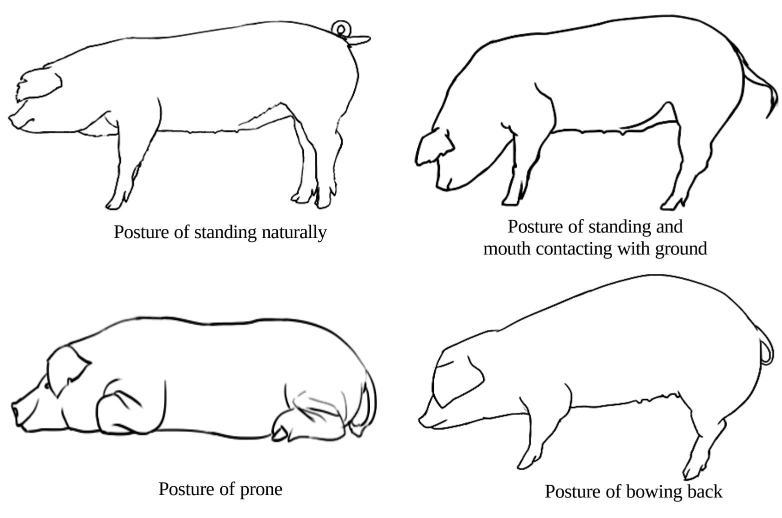

Fig. 1: Four typical postures ofswine when ultrasonic measuring

Data's statistics and analysis: Using the SPSS 18.0 Software process take the variance analysis and Pair t-test to analyze the data of instrument, posture and people. Calculate the correlation coefficient. Using excel to calculate the degree of deviation, among them degree of deviation's 2 parameter are the Standard Deviation of the Error (ESD) and the Root Mean Square Error (RMSE) and then researchers make the regression equation of the somatometry and the body measurement.

Degree of deviation somatometry of the back fat and body measurement's absolute deviation level can be treat as the degree of deviation of somatometry and the true value:

$$Y = \frac{\sum_{i=1}^{n}|b_i - t_i|}{n} \quad (1)$$

Where:

Y (cm/cm^2) = The mean value of somatometry and body measurement's mean absolute deviation

b_i (cm/cm^2) = The number i pig's live back fat thickness or eye muscle area measurement

Accuracy evaluate the accuracy of the measurement result commonly using correlation coefficient to describe. However in some situation, the correlation index is easy to be influenced by the sample number and can not well reflect the deviation of the measured value and the real value (Houghton and Turlington, 1992).

Houghton and Turlington (1992), Robinson *et al.* (1992) and Herring *et al.* (1994) using the Error (ESD) and the Root Mean Square Error (RMSE) to evaluate the accuracy of the measurement. ESD and RMSE's equation are 2 and 3:

$$ESD = \sqrt{\frac{\sum (X_2 - X_1)^2}{n}} \quad (2)$$

$$RMSE = \sqrt{\frac{\sum\left[(X_2 - \bar{X}_2) - (X_1 - \bar{X}_1)\right]^2}{n-1}} \quad (3)$$

Where:

X_1 (cm/cm^2) = The body measurement's back fat or eye muscle area

X_2 (cm/cm^2) = The B ultrasound live measurement's back fat or eye muscle area

$\bar{X}_1$ (cm/cm^2) = The average value of the body measurement's back fat or eye muscle area

$\bar{X}_2$ (cm/cm^2) = The average value of the B ultrasound live measurement's back fat or eye muscle area

n = The detected sample number

RESULTS AND DISCUSSION

The influence of different instrument's measurement: Instrument live back fat measuring and body measurement's absolute deviation value level is instrument live back fat measuring and the true value's degree of deviation.

As researchers can see in the Table 1, AQUILA VET, SASET, CX-500, LEAN-METER, RH2008V live back fat measuring and body measurement's degree of deviation are 0.336, 0.450, 0.470, 0.557 and 0.570 cm, respectively among which the AQUILA VET's degree of deviation is the lowest. On the other hand, instrument live measurement and body measurement's regression line slope is also an index to evaluate the degree of deviation. Equal volume contour (full line, slope is 1, intercept is 0) show that the instrument live measurement and body measurement is the same, the accuracy is best. AQUILA VET, SASET, CX-500, LEAN-METER and RH2008V measure the regression line slope are 0.981, 0.947, 0.921, 1.116 and 1.302 (Fig. 2a-e). The more the slope close to 1, means the less the degree of deviation is the higher the accuracy is. Five instrument's accurate rate from high to low are AQUILA VET, SASET, CX-500, LEAN-METER and RH2008 V in instrument live measurement and body measurement's different aspects, AQUILA VET, SASET and body measurement have no significant difference ($p>0.05$) but CX-500 and body measurement have significant difference ($p<0.05$), LEAN-METER and RH2008 V live back fat measurement and body measure measurement has extremely significant difference ($p<0.01$, Table 1). RMSE and ESD are all the smallest value that means instrument live measurement and body measurement's accuracy is high. Five instrument's RMSE and ESD's change are all the same, sequence from high to low are AQUILA VET, SASET, CX-500, LEAN-METER and RH2008V. So, researchers can see that AQUILA VET live back fat measurement's accuracy is the highest. It's measured value and body measurements correlation index are the highest, degree of deviation, root mean square error and the standard deviation of the error are the smallest.

Table 1: The accuracy of five types ofultrasonic machines for the prediction of backfat thickness in the live swine

Machines	n	Bias/cm[a]	Correlation coefficient[b]	p-values[c]	RMSE	ESD
AQUILA VET	48	0.336±0.297	0.962	0.241	0.467	0.446
SASET	48	0.450±0.340	0.927	0.108	0.568	0.562
CX-500	48	0.470±0.382	0.947	0.030	0.572	0.552
LEAN-METER	48	0.557±0.401	0.954	0.000	0.645	0.636
RH2008V	48	0.570±0.404	0.962	0.000	0.697	0.677

[a]Bias: Absolute deviation between backfat thickness of ultrasonic machines measuring and carcass measurements; [b]Correlation coefficient: Correlation coefficient between backfat thickness of ultrasonic machines measuring andcarcass measurements; [c]p-values: p-values between backfat thickness of ultrasonic machines measuring and carcass measurements

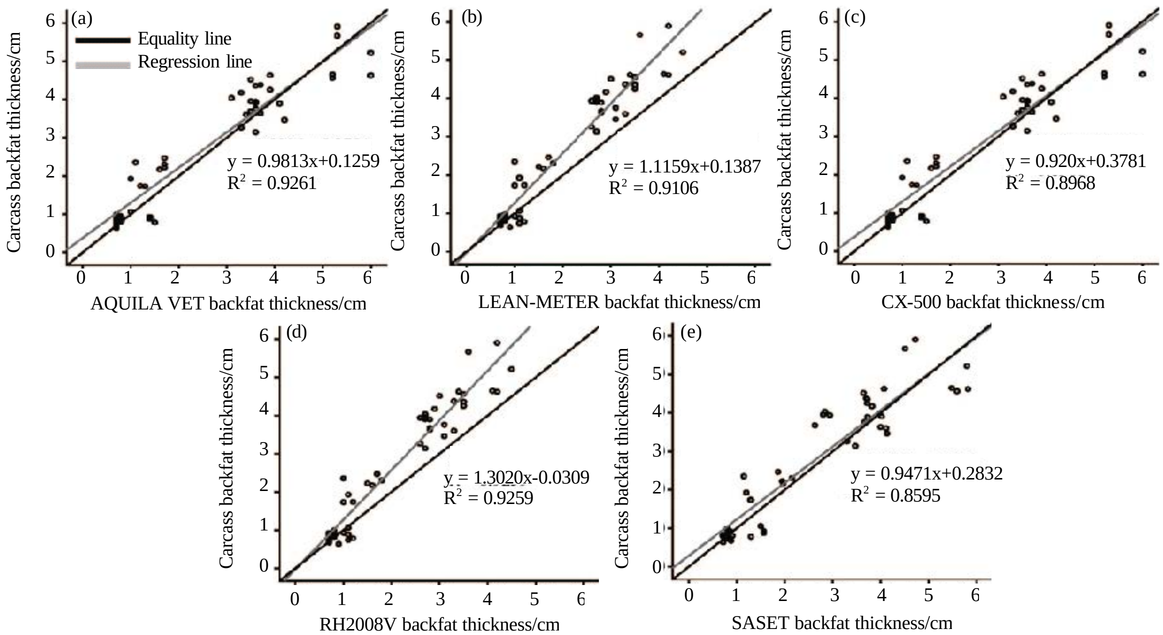

Fig. 2: Ultrasonic machines versus carcass backfat thickness measurements (n = 48). Equality line has intercept = 0 and slope = 1

Different pose of pig's influence to the somatometry: Different pose of pig's influence the ultrasonic measurement accuracy to the somatometry. Researchers did the T analyze to the different pose of somatometry and body measurement. The results show that in the standing naturally and prone position, back fat measurement and body measurement have no significant difference ($p>0.05$) standing with mouth touch the ground's back fat measurement and body measurement has significant difference ($p<0.05$) there are extremely much significant difference in bow back posture ($p<0.01$), test the back fat and body measurement degree of deviation in the posture of prone, standing naturally, bow back and standing with mouth touch the ground's are 0.056, 0.042, 0.123 and 0.078 cm (Table 2). The eye muscle area measurement and body eye muscle area in standing naturally, standing with mouth touch the ground and bow back position have no significant difference ($p>0.05$) lie prostrate's eye muscle area measurement and body measurement have significant difference ($p<0.05$) test the back fat and body measurement degree of deviation in the posture of prone, standing naturally, bow back and standing with mouth touch the ground's are respectively 2.618, 2.036, 2.280 and 2.057 cm^2 (Table 2). When the pig is prone, pig's muscle and the ground crush to each other then the muscle's characteristic is changed it lead to the big difference of the true value eye muscle area. When the pig bow it's back, the eye muscle is in strain position and has remarkable difference between the real value ($p<0.05$). On the other hand, the equalvolume contour (solid line, slope is 1, intercept is 0) express the posture living measurement and body measurement are the same which can be consider some pose measurement value to be the real value which has a good accuracy. When the slope is the same, the smaller the intercept's absolute value is the more accuracy it is. Compare with the prone posture, the measure value is more accurate when the pig is standing (Fig. 3a and b). When the intercept is minimum, the slope is close to 1 and the accuracy is high. Compare with standing with mouth touch the ground, the prone position has more accuracy (Fig. 3a and d). Compare with the change of slope, the change of the intercept is larger than the accuracy of standing with mouth touch the ground

Table 2: The accuracy of ultrasonic prediction of backfat thickness by four typical postures of measuring

Postures of swine when ultrasonic measuring	n	Bias/cm[a]	Correlation coefficient[b]	p-values[c]	RMSE	ESD
BF						
1	33	0.056±0.048	0.994	0.208	0.071	0.064
2	33	0.042±0.038	0.996	0.226	0.056	0.056
3	33	0.123±0.073	0.990	0.000	0.112	0.091
4	33	0.078±0.042	0.995	0.011	0.073	0.073
LMA						
1	33	2.618±1.774	0.882	0.028	3.145	2.931
2	33	2.036±1.763	0.905	0.201	2.673	2.640
3	33	2.280±1.965	0.825	0.203	2.806	2.786
4	33	2.057±1.868	0.899	0.250	2.757	2.739

BF: Backfat thickness; LMA: Longissimus Muscle Area; 1: Posture of prone, 2: Posture of standing naturally, 3: Posture of bowing back, 4: Posture of standing and mouth contacting with ground; [a]bias: Absolute deviation between backfat thickness by four typical postures of measuring and carcass measurements; [b]Correlation coefficient: correlation coefficient between backfat thickness backfat thickness by four typical postures of measuring and carcass measurements; [c]p-values: p-values between backfat thickness backfat thickness by four typical postures of measuring and carcass measurements

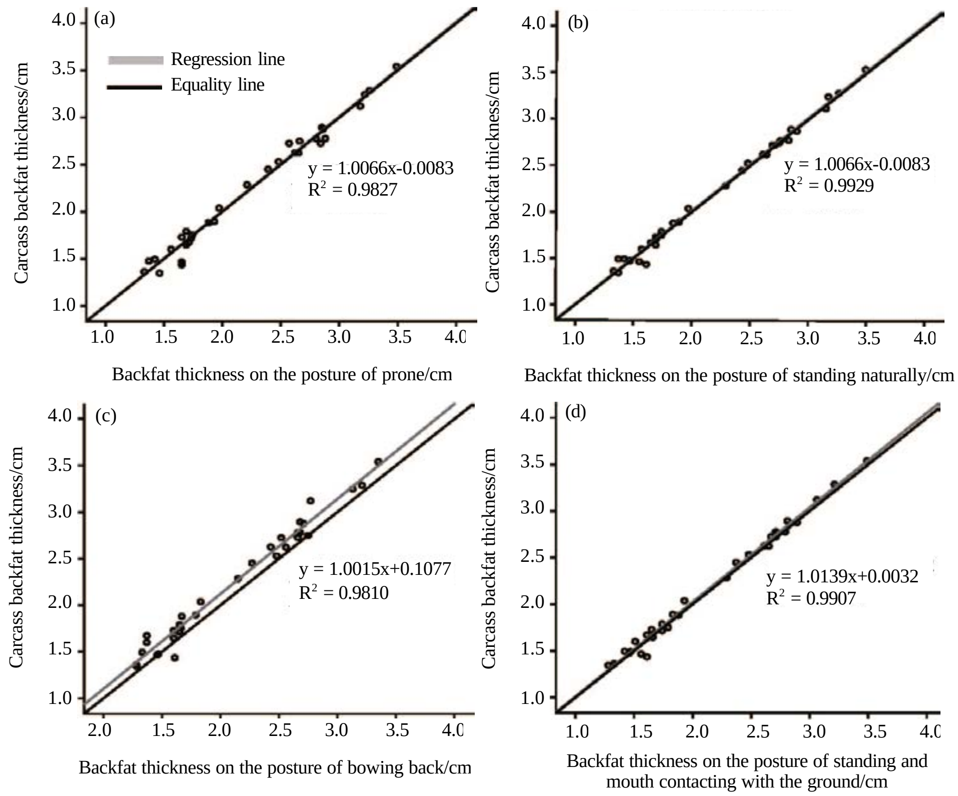

Fig. 3: Ultrasonic backfat thickness by swine four typical postures versus carcass backfat thickness measurements (n = 33). Equality line has intercept = 0 and slope = 1

(Fig. 3c and d). Measurement of back fat and eye muscle area all have high correlation index which are all over 0.82. From big to small, the back fat's ESD and RMSE value are standing naturally, prone, standing with mouth touch the ground, bow back among them the RMSE measurement of prone is twice than than standing naturally (Table 2). The other three posture except prone's eye muscle area living measurement and the body measurement are all have no significant difference ($p>0.05$). So, the nature standing is the best posture of living measurement.

The influence of different people recognize the image: Take the t-test to different people's back fat measurement and the body measurement's true value; the No. 1, 2 and 3 people's recognize to the back fat and the eye muscle have no significant difference ($p>0.05$) the No. 4 and 5 people's recognize to back fat and eye muscle have respectively extremely significant difference ($p<0.01$) and significant difference ($p<0.05$). No. 1, 2, 3, 4 and 5 technicist's back fat and eye muscle area's absolute deviation value are 0.052, 0.060, 0.068, 0.131, 0.121, 1.521, 1.375, 1.563, 1.950 and 2.024 (Table 3), researchers can see that the highly trained No. 1, 2 and 3 people recognize image's degree of deviation is lower than the low trained No. 4 and 5 people. On the other hand, No. 5 people's image recognition of back fat and body measurement's regression equation slope are all very close but the intercept differences are very big (Fig. 4a-e). As the slope's changed is little, the bigger the intercept's absolute value is the lower the accuracy is. So, experienced people's measurement accuracy is higher than the less experience people. The 5 people's back fat measurement's correlation index is very high, all are over 0.99 but eye muscle area's measurement is >0.81. Compare with the highly trained people when the low trained people recognize the back fat and eye muscle area's RMSE and ESD value are all very large (Table 3). In a word, the highly trained people's accuracy to the image measurement is higher than the low trained people.

The accuracy of ultrasonic somatometry is the key of the breeding research and the factors influencing its accuracy include personnel, instruments, species and environment and so on. This research showed that ultrasonic instrument, pig posture under somatometry and image recognition of surveyors are all the main factors influencing the accuracy of measurement under the same environment and condition.

The accuracy of ultrasonic instrument which is a common instrument for somatometry is a prerequisite for somatometry. See (1998) believed that the accuracy of

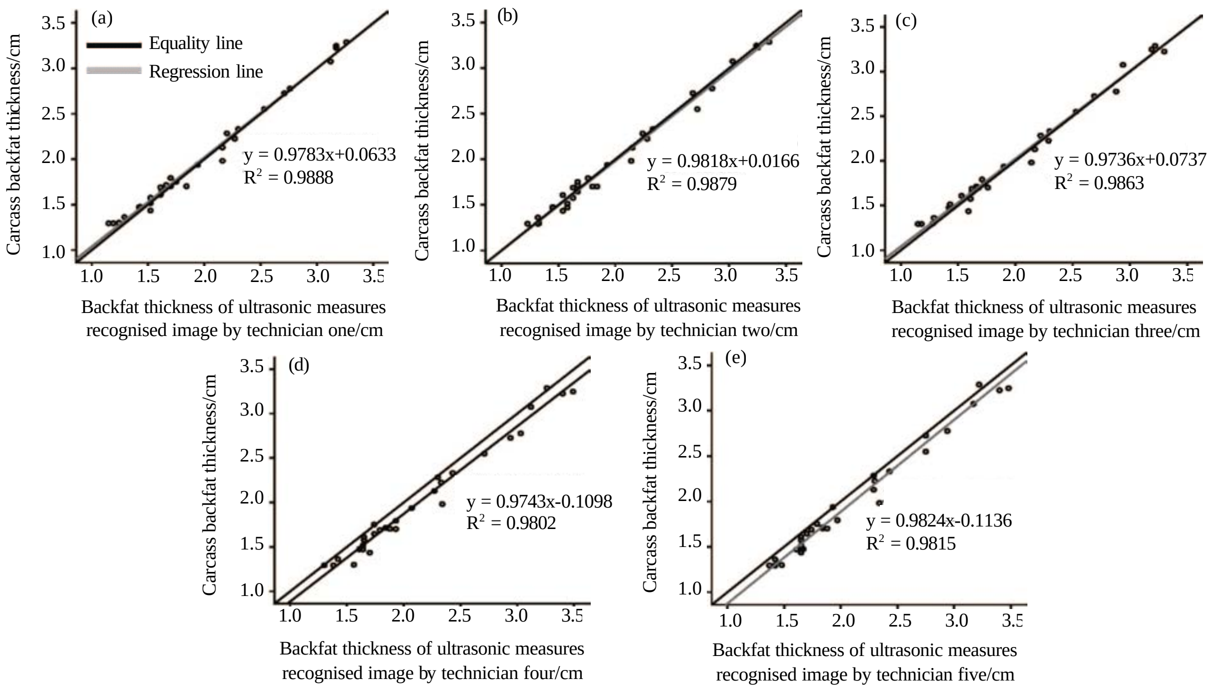

Fig. 4: Ultrasonic backfat thickness recognised by five technicians versus carcass backfat thickness measurements (n = 31). Equality line has intercept = 0 and slope = 1

Table 3: The accuracy of ultrasonic measures image recognised by five technicians

Technicians	n	Bias/cm[a]	Correlation coefficient[b]	p-values[c]	RMSE	ESD
BF						
1	31	0.052±0.044	0.994	0.101	0.070	0.068
2	31	0.060±0.042	0.994	0.121	0.072	0.070
3	31	0.068±0.041	0.993	0.115	0.077	0.075
4	31	0.131±0.085	0.990	0.000	0.159	0.090
5	31	0.121±0.076	0.991	0.000	0.146	0.085
LMA						
1	28	1.521±1.070	0.896	0.099	1.813	1.846
2	28	1.375±1.157	0.922	0.079	1.660	1.700
3	28	1.563±1.652	0.855	0.223	1.875	2.039
4	28	1.950±1.069	0.882	0.019	2.273	2.248
5	28	2.024±1.305	0.813	0.017	2.273	2.478

BF: Backfat thickness; LMA: Longissimus Muscle Area; [a]Bias: Absolute deviation between backfat thickness (longissimus muscle area) of ultrasonic measures image recognised by technicians and carcass measurements; [b]Correlation coefficient: Correlation coefficient between backfat thickness (longissimus muscle area) of ultrasonic measures image recognised by technicians and carcass measurements; [c]p-values: p-values between backfat thickness (longissimus muscle area) of ultrasonic measures image recognised by technicians and carcass measurements

somatometry with type-B ultrasound is higher than that with type-A ultrasound. But type-A ultrasound has the function of direct reading and is more cheap, portable, universal. To study the differences of somatometry between different type-A ultrasound, see set the measured data of type-B ultrasound as the true value and compared the measurement results of five different type-A ultrasound to type-B ultrasound and found that different type-A ultrasound had extremely significant difference ($p<0.01$). In order to study the differences of somatometry between different instruments, somatometry with one type-A ultrasound and four type-B ultrasound were compared with carcass measurement. The results showed that backfat somatometry with ultrasonic instrument had a high accuracy and the correlation coefficients were all above 0.92. But there were big differences on significant differences between different instruments and carcass measurements (Table1). The accuracy of type-A ultrasonic somatometry was lower than type-B, except for RH2008V. The principles of type-A ultrasound and type-B ultrasound are different. A ultrasound is waveform measured by a quartz crystal to a point while B ultrasound is real-time image measured by a plurality of quartz crystal to multiple point measurement. The probe of RH2008V is a 3.5 MHz waterproof mechanical fan while the probe of the other B ultrasound instruments is linear array. Therefore, proper instrument and probe for somatometry of backfat will help to get values of higher accuracy.

The position of pig when measured is the direct factor influencing the accuracy of measurement. It will reduce the accuracy of the measurement if the posture of pig changes when freezing image (Miller, 1996). This study showed that backfat measurement and carcass measurement had very significant difference in bowing-back posture ($p<0.01$) and there was significant difference in a posture of standing and mouth contacting ground ($p<0.05$, Table 2). The main reason for the discrepancy may be that the distraction state of ocular muscle when bowing back which stretched skin and squeezed the skin sebum layer resulted in the lower measured backfat. There was no significant difference between somatometry and carcass measurements in natural standing and prone position but both SDE and RMSE in prone position were much higher than in natural standing position. Prone position had no effect on the results of backfat measurement but it may significantly influence the accuracy of ocular muscle area. This may be due to relaxation of back muscle in prone position and great change in extent of ocular tension.

So, it is the best to freeze clear-cut image when pig stands naturally in backfat somatometry of breeding research thus measured data is more accurate. In particular, avoid freezing image in bowing-back posture, otherwise the value obtained will differs the real value much.

Surveyors are the key factor of influencing the measured results of type-B ultrasound performance. See (1998) compared the somatometry with type-A ultrasound of three surveyors and found that there was a significant difference ($p<0.05$). Researchers divided the error caused by surveyors into error when acquiring images from living organism and error caused by image recognition and conducted statistical analysis for the latter. Researchers found that in the image recognition of backfat thickness and ocular muscle area among different technical personnel there was a significant difference in surveyors trained with a low degree in the image recognition of backfat ($p<0.05$) and there was an extremely significant difference in the image recognition of ocular muscle area ($p<0.01$, Table 3). As a result of the differences in training level and the image contour recognition when different technical personnel identifying image, backfat thickness and ocular muscle area measurements have significant difference. The range of backfat and ocular muscle area deviated from the true values among the surveyors with higher training degree (number 1, 2 and 3) is 0.052-0.068 cm ($p>0.05$), 1.375-1.563 ($p>0.05$), respectively. While the range of backfat and ocular muscle area deviated from the true values among the surveyors with lower training degree is 0.121-0.131 cm ($p<0.01$), 1.950-2.024 cm^2 ($p<0.05$), respectively. Therefore, enhancement of the training degree of surveyors can improve the accuracy of measurement.

CONCLUSION

Surveyors, instruments and pig posture have great influence on the accuracy of the measurement in somatometry and carcass measurement with ultrasound. Selection with proper instrument and probe brings higher accuracy (degree of deviation is 0.336 cm) the accuracy of somatometry is the best when pig stands naturally (the degree of deviation of backfat is 0.042 cm, ocular muscle area is 2.036 cm^2) which shows no significant difference with the slaughter measurement ($p<0.05$) and the highest correlation coefficient (backfat 0.996, ocular muscle area 0.905) there is a significant difference in image recognition among surveyors with lower training degree ($p<0.05$) the difference between the personnel can be reduced by strengthening the image recognition training thus further improve the accuracy of personnel measurement. Hence, improvement of the proficiency of technical personnel, suitable instrument and freezing image in natural stance of pig can effectively improve the accuracy of somatometry.

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