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Choice of probing site for estimation of carcass lean percentage in Piétrain pig using the real-time ultrasound

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Real-time ultrasound data of backfat thickness, *longissimus thoracis* muscle depth and *longissimus thoracis* muscle area were obtained from 210 Piétrain pigs (98 gilts and 112 barrows) using the Pie Medical Scanner 200 equipped with an animal science probe (ASP-18) and frequency of 3.5 MHz. They were fed *ad libitum* and slaughtered at an average age of 213 days for an average weight of 101 kg. The day before slaughter, four longitudinal and transverse images were taken on the level of the last rib and the tenth rib from each animal. The repeatability of ultrasound last rib backfat (ULRBF) measurements was similar to that of tenth rib backfat (UTRBF) (t = 0.87). Ultrasound last rib *longissimus thoracis* muscle depth (ULRMD) and area (ULRMA) measurements were more repeatable than those corresponding to the tenth rib. The best correlation between carcass lean percentage estimated by the Fat Lean Meter (CGM lean) and ultrasound carcass measurements was obtained with backfat thickness (r = -0.51). The correlation between CGM lean percentage and ULRMD and between CGM lean percentage and ULRMA were higher than those between CGM lean percentage and UTRMD and between CGM lean percentage and UTRMArespectively. When the CGM lean percentage was predicted from ultrasound backfat thickness, the accuracy of the regression equation was the same regardless of the probing site (last or tenth rib). On the other hand, when *longissimus thoracis* muscle measurements (depth and area) are included together with backfat thickness in prediction equations, the last rib was more accuracy. Therefore, the last rib site can serve as the probing site for CGM lean percentage prediction.
Keywords. Swine, pork, ultrasound, *longissimus thoracis* muscle, backfat, carcass lean, carcass composition.

Choix du site de sondage dans l'estimation de la teneur en viande maigre du porc Piétrain par l'ultrasonographie en temps réel. Des mesures ultrasonographiques de l'épaisseur du lard dorsal, de l'épaisseur et de la surface du muscle *longissimus thoracis* ont été réalisées sur 210 porcs de race Piétrain dont 98 femelles et 112 castrats avec le scanner Pie Medical 200 équipé d'une sonde ASP-18, de fréquence 3,5 Mhz. Les animaux ont été nourris *ad libitum* et abattus à un âge moyen de 213 jours pour un poids moyen de 101 kg. La veille de l'abattage, quatre images longitudinales et transversales ont été prises au niveau de la dernière et de la dixième vertèbres thoraciques de chaque porc. La répétabilité de la mesure de l'épaisseur du lard dorsal de la dernière côte (ULRBF) est similaire à celle de la dixième côte (UTRBF) (t = 0,87). Les mesures de l'épaisseur (ULRMD) et de la surface (ULRMA) du muscle *longissimus thoracis* de la dernière vertèbre thoracique ont été plus répétables que celles de l'épaisseur (UTRMD) et de la surface (UTRMA) de la dixième côte respectivement. La meilleure corrélation entre la teneur en viande maigre (TVM) de la carcasse estimée par le Capteur Gras – Maigre et les mesures à ultrasons de la carcasse a été obtenue avec l'épaisseur du lard dorsal (r = -0,51). La corrélation entre TVM et ULRMD et celle entre TVM et ULRMA ont été plus importantes que celles obtenues entre TVM et UTRMD et entre TVM et UTRMA respectivement. Lorsque la teneur en viande maigre est prédite à partir de l'épaisseur du lard dorsal, la précision de l'équation de régression est similaire quel que soit le site de mesure. Par contre, en ajoutant l'épaisseur ou la surface du muscle *longissimus thoracis* à l'épaisseur du lard dorsal dans l'équation de régression, la dernière vertèbre thoracique a présenté la meilleure précision. De tout ce qui précède, la dernière côte est le meilleur site de mesure pour la prédiction de la TVM.
Mots-clés. Porcin, viande porcine, ultrasons, muscle *longissimus thoracis*, lard gras, viande maigre, composition de la carcasse.

1. INTRODUCTION

The ultrasonic technique has been used since the late 1950s in the prediction of pork carcass composition (Szabo *et al.*, 1999). It is based on the measurements of backfat thickness, *longissimus thoracis* muscle depth and *longissimus thoracis* muscle area of the animal before slaughter. Real-time ultrasound imaging in two-dimensions has been used more recently in the estimation of carcass composition and offers the possibility of predicting the lean meat content in live animal. The correlation between backfat thickness, *longissimus thoracis* muscle depth and *longissimus thoracis* muscle area measurements in the live animal and those obtained on the carcass show a great degree of variability (McLaren *et al.*, 1991; Houghton, Turlington, 1992; Szabo *et al.*, 1999). The effects of operators and machines in ultrasound measurements have been observed in cattle, as well as in sheep and pigs (McLaren *et al.*, 1991). For a single animal, there exists an important variability of measurements from one probe site to another (Fisher, 1997). In general, measurements on live pigs are taken anywhere from the first rib to the last lumbar vertebra on the midline, and as far as 13 cm off the midline (Sather *et al.*, 1986; Fisher, 1997). In several pork carcass lean estimation studies, the ultrasound measurements at the tenth or last rib are the most often used (McLaren *et al.*, 1991; Gresham *et al.*, 1994; Moeller *et al.*, 1998; Dourmad *et al.*, 2001).

The aim of this study was to find the optimal probing site between ultrasound measurements at the tenth and the last ribs for estimation of lean meat percentage in live Piétrain and stress-negative Piétrain.

2. MATERIALAND METHODS

2.1. Data

Data from 210 Piétrain pigs including 98 gilts and 112 barrows were recorded from 1998 to 1999 at the experimental station of the Faculty of Veterinary Medicine at the University of Liège (Belgium). Among those Piétrain pigs, 40 were homozygous stress-negative (CC), 102 were heterozygous stress-negative (CT) and 68 were homozygous stress-positive. The genotype at the halothane locus was determined by the Ryanodine test according to Fujii *et al.* (1991) and Grobet *et al.* (1992). Piglets were weaned at 26 days, corresponding to the time of castration for males. Fattening began at an average age of 85 days. Pigs were grouped by 10 according to age, and fed *ad libitum*. The pigs were slaughtered at an average age of 213 days with an average weight of 101 kg. The day before slaughter, ultrasonic images were taken *in vivo* with a Pie Medical Scanner 200 (Pie Medical equipment BV, Maastricht, The Netherlands) equipped with an animal science probe (ASP-18) and a frequency of 3.5 MHz. Pigs were immobilised in a scanning corridor to standardise the image collection procedure. To obtain good acoustical contact and to avoid the presence of air bubbles between the probe and skin surface, the site was cleaned and vegetable oil was used. Each animal was scanned four times for each site. The longitudinal images were taken parallel and 6 cm from the dorsal midline at the tenth and the last ribs and the transverse images were taken perpendicular to the midline at the tenth and the last ribs using an ultrasound standoff guide conformed to the curvature of the pig's back, mounted on a linear probe. Ultrasound last rib backfat (ULRBF), ultrasound tenth rib backfat (UTRBF), ultrasound last rib *longissimus thoracis* muscle depth (ULRMD) and ultrasound tenth rib *longissimus thoracis* muscle depth (UTRMD) were measured from longitudinal images (**Figure 1**). Ultrasound last rib *longissimus thoracis* muscle area (ULRMA) and ultrasound tenth rib *longissimus thoracis* muscle area (UTRMA) were measured from transverse images (**Figure 2**). Backfat thickness and *longissimus thoracis* depth were measured from longitudinal image and *longissimus thoracis* area were measured from transversal image according to the recommendation of Gresham (1995). The features of acceptable images include the following qualities: clear visible back fat layers, *longissimus thoracis* muscle layer and ribs, with no sign of uneven coupling or poor transducer contact; *longissimus thoracis* muscle area taken from the cross-section clearly

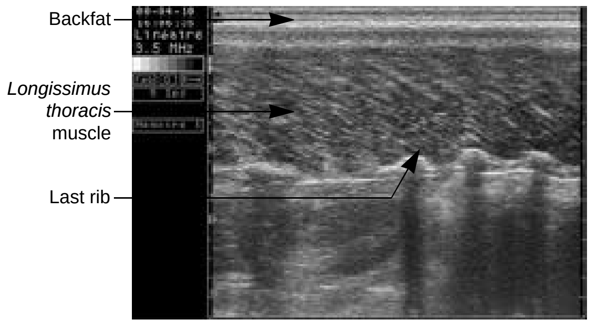

Figure 1. Ultrasound longitudinal section image of Pietrain pig in dorso-lumbar region — *Image aux ultrasons de la coupe longitudinale de la région dorso-lombaire chez le porc Piétrain.*

Figure 2. Ultrasound cross-sectional image of Pietrain pig at the dorso-lumbar region — *Image aux ultrasons de la coupe transversale de la région dorso-lombaire du porc Piétrain.*

visible, well delimited with minimal artefacts. The selected images were transferred to a personal computer and recorded according to animal identification number. Measurements of ultrasound backfat thickness (UBFT), ultrasound *longissimus thoracis* muscle depth (ULMD) and ultrasound *longissimus thoracis* muscle area (ULMA) were made using image analysis software from Pie Medical: Open Data Transfer (ODT) and Eview (Echo Image Viewer), version 1 (Pie Medical equipment BV, Maastricht, the Netherlands).

Prior to being transported to the slaughterhouse, food was withheld from the animals for 24 hours. The carcass lean meat percentage (CGM lean) was estimated by a CGM (Capteur Gras-Maigre) equipped with an 8 mm diameter Sydel probe according to the recommendations of the Ministère des classes moyennes et de l'agriculture (1999):

$$Y = 59.902386 – 1.060750X_1 + 2.229324X_2$$

where
Y = carcass lean meat percentage estimate;
X_1 = backfat thickness (including the skin) expressed in millimetres measured at 6 cm lateral of the carcass midline the 3rd and 4th last ribs;
X_2 = *longissimus thoracis* muscle depth expressed in millimetres, measured at the same time and same place as X_1.

The measured values were converted into an estimate value of carcass lean content by the same apparatus.

2.2. Statistical analysis

The repeatability of backfat thickness, *longissimus thoracis* muscle depth and *longissimus thoracis* muscle area was calculated for each site. A mixed linear model including the fixed effects of halothane genotype, sex and the random effect of the animal was adjusted to the data.

$$Y_{ijk} = \mu + T_i + S_j + a_{ijk} + e_{ijk}$$

where
Y_{ijk} = backfat thickness, *longissimus thoracis* muscle depth or *longissimus thoracis* muscle area of the pig k, halothane genotype i and sex j;
μ = overall means;
T_i = fixed effect of halothane genotype i (homozygous stress-negative CC, heterozygous stress-negative CT and homozygous stress-positive TT);
S_j = fixed effect of the sex j (gilt and barrow);
a_{ijk} = random effect of the animal within the halothane genotype and sex ;
e_{ijk} = residual errors.

The interaction between genotype and sex was not significant and was ignored in the final model. Variance components of backfat thickness, *longissimus thoracis* muscle depth and *longissimus thoracis* muscle area were estimated separately by probing site. Estimation was made using the variance components estimation procedure by restricted maximum likelihood random models (REML) of SAS (1989).

Repeatability is defined as the correlation between repeated measures on the same animal. This value was calculated by site. In all cases, repeatability was calculated as an intraclass correlation (t) as follows:

$$t = \frac{Var(a)}{Var(a) + Var(e)}$$

where
Var (*a*) = between-animal variance;
Var (*e*) = residual variance.

The sampling variance for intraclass correlation was calculated according to Falconer (1989):

$$Var(t) = \frac{2\left[1+(n-1)\,t\right]^2 (1-t)^2}{n\,(n-1)(N-1)}$$

where
Var (t) = variance of intraclass correlation;
t = intraclass correlation;
n = the number of repeated measurements;
N = number of animals.

The correlations between ultrasound measurements in the live animal and those of the carcass were obtained by PROC CORR of SAS (1989). Regression analyses were carried out using the General linear model procedure (PROC GLM) and the regression procedure (PROC REG) of SAS (1989).

2.3. Results and discussion

Means, standard deviations, minima and maxima of the traits are shown in **table 1**. The average live weight and carcass weight were respectively 101 kg and 86 kg, and the percentage of lean content was 65%. Ultrasound backfat thickness, *longissimus thoracis* depth and *longissimus thoracis* area measurements were 17.3 mm, 55.8 mm and 54.4 cm^2 respectively for the last rib, and 18.6 mm, 51.1 mm and 50.3 cm^2 respectively for the tenth rib. Halothane genotype and sex effects on ultrasound measurements was highly significant ($p<0.001$) according to analysis of variance results for each site.

Results of ultrasound measurement repeatability by probing site are given in **table 1**. The repeatability of ULRBF measurements was similar to that of

Table 1. Means, standard deviations, minima and maxima of carcass traits. Components of variance and repeatability of ultrasound measurements. *Composantes de la variance et répétabilité des mesures ultrasonographiques — Moyenne, déviation standard, minimum et maximum des caractéristiques de la carcasse*.

Variables	Number	Means	SD	Min.	Max.	Sources of variation	Between animal variance	Residual variance	Total variance	Repeatability ± SE
Age at slaughter (day)	210	212.7	14.7	187	261					
Live weight (kg)	210	101	7.2	66	143					
CWT (kg)	210	85.7	9.9	55	122					
CGM lean (%)	210	64.9	3.9	52.8	72.9					
ULRBF (mm)	210	17.29	2.59	11.3	23.6	ULRBF	13.05	1.93	16.98	0.87 ± 0.017
ULRMD (mm)	210	55.85	6.36	44.6	69.1	ULRMD	28.31	3.6	31.91	0.89 ± 0.014
ULRMA(cm^2)	210	54.38	7.43	41	71	ULRMA	25.83	9.28	35.11	0.74 ± 0.031
UTRBF (mm)	192	18.57	4.5	10.2	27	UTRBF	13.45	1.98	15.43	0.87 ± 0.017
UTRMD (mm)	192	53.1	6.97	42.1	72	UTRMD	22.93	3.94	26.87	0.85 ± 0.02
UTRMA(cm^2)	192	50.34	6.55	34.9	62.6	UTRMA	24.64	9.75	34.67	0.70 ± 0.037

SD = Standard deviation — *déviation standard* ; SE = Standard error — *erreur standard* ; CWT = Hot carcass weight — *Poids chaud de la carcasse* ; CGM lean = carcass lean percentage estimated by the Fat Lean Meter — *Pourcentage en viande maigre de la carcasse estimé par le Capteur Gras-Maigre* (CGM) ; ULRBF = Ultrasound last rib backfat — *Lard dorsal mesuré à l'ultrasonographe au niveau de la dernière côte* ; ULRMD = Ultrasound last rib muscle depth — *Épaisseur du muscle* longissimus thoracis *mesurée à l'ultrasonographe au niveau de la dernière côte* ; ULRMA = Ultrasound last rib muscle area —*Surface du muscle* longissimus thoracis *mesurée à l'ultrasono - graphe au niveau de la dernière côte* ; UTRBF = Ultrasound tenth rib fat — *Lard dorsal mesuré à l'ultrasonographe au niveau de la dixième côte* ; UTRMD = Ultrasound tenth rib muscle depth — *Épaisseur du muscle* longissimus thoracis *mesurée à l'ultrasonographe au niveau de la dixième côte* ; UTRMA = Ultrasound tenth rib muscle area —*Surface du muscle* longissimus thoracis *mesurée à l'ultrasonographe au niveau de la dixième côte.*

UTRBF (t = 0.87 ± 0.017). However, residual variance and between animal variance were higher in tenth rib than in last rib. ULRMD was more repeatable (0.89 ± 0.014) than UTRMD (0.85 ± 0.02). For the *longissimus thoracis* muscle area, the lowest repeatability (0.70) was obtained for UTRMA with a high standard error (0.037) whereas ULRMAwas 0.74 ± 0.031. Regardless of the probing site, ultrasound *longissimus thoracis* muscle area was less repeatable than backfat thickness and *longissimus thoracis* muscle depth. The errors of the measures are due to image artefacts. The restraining of the animal plays a great role in the quality of the ultrasound images. The higher repeatability at ULRMD and ULRMA than at UTRMD and UTRMA could be related to the ease of localisation of the last rib by palpation, and by the screen observation. Inversely, it was difficult to locate exactly the probing site at the tenth rib. This difficulty to locate the site was observed particularly for UTRMA. The repeatability of ULMA was generally low compared to those of UBFT and ULMD. This difference could be due to the measurement errors related to the precision with which the *longissimus thoracis* perimeter limits are delineated. In the Piétrain breed, repeatability from 0.61 to 0.77 and 0.91 to 0.98, respectively for UBFT and ULMA, have been reported for several probing sites in Germany by Busmann *et al.* (1991) and they observed that the ultrasonic probing site on the last rib give the best accuracy in carcass lean prediction. During the comparison of three ultrasonic machines (Renco, Krautkrämer USM2 and Combison 310) for lean meat content prediction in live Piétrain and Large White, the repeatability ranging from 0.5 to 0.7 was observed by Krieter *et al.* (1990) for the UBFT and ULMD, and additionally, lowers values were determined for backfat measurements at the 3/4th lumbar vertebra than the last rib. Improvement of the accuracy of ultrasound measurements could be provided by taking the same measure several times on the same animal. According to Hassen *et al.* (1999), when the number of images per animal increases from one to two or from one to four, the repeatability improves and the standard error of animal mean measures decreases by 29% and 50% respectively.

Results of correlation between ultrasound measurements and carcass lean percentage are given in **table 2**. CGM lean was positively correlated with ULMD and ULMA and negatively correlated with UBFT. The best correlation between CGM lean and ultrasound measurements was obtained with backfat thickness (r = -0.51, p< 0.001). The correlation between CGM lean and ULRMD (r = 0.5, p< 0.001) was higher than that between carcass lean and UTRMD (r = 0.42, p< 0.001). The lowest correlation was obtained between CGM lean and UTRMA (r = 0.31, p< 0.001). The results of this study are similar to the findings of Smith *et al.* (1992) who reported a correlation of 0.25 (p< 0.1) between UTRMA and percentage of lean cut, whereas the

Table 2. Correlation between carcass weight, carcass lean percentage and ultrasound measurements — *Corrélation entre le poids de la carcasse, la teneur en viande maigre et les mesures ultrasonographiques*.

Variables	CWT	ULRBF	ULRMD	ULRMA	UTRBF	UTRMD	UTRMA
CGM lean	-0.185 *	-0.507 ***	0.496 ***	0.321 ***	-0.511***	0.423***	0.313***
CWT		0.461 ***	0.297 **	0.566 ***	0.421***	0.292**	0.587***
ULRBF			0.01	0.269 **	0.817***	0.015	0.122
ULRMD				0.639 ***	0.110	0.778	0.562***
ULRMA					0.301**	0.223**	0.707***
UTRBF						0.023	0.252**
UTRMD							0.640***

* = Significant at —Significatif à $p< 0.05$; ** $p< 0.01$; ***$p< 0.001$.
Abbreviations: see table 1 — Abréviations : voir tableau 1.

correlation between ULRBF and percentage of lean cuts was - 0.51 ($p< 0.01$).

When the carcass lean content was predicted from UBFT, the accuracy of the regression equation was the same ($R^2 = 0.26$) regardless of the probing site (last or tenth rib). The accuracy of the carcass lean percentage predicted from real-time ultrasonic scans was more significantly improved by including *longissimus thoracis* muscle measurements (depth and area) together with backfat thickness in last rib ($R^2 = 0.54$; RSD = 2.27; C(p) = 1.55) than tenth rib ($R^2 = 0.51$; RSD = 2.71; C(p) = 3.2) in prediction equations[1].

From the results of this study, the last rib was the best site of ultrasound measurements. Moreover, this site could be used for ease of location by palpation contributing to higher repeatability of ultrasound measurements. Different devices based on different techniques (optical versus ultrasonic) could possibly cause differences in fat thickness measurements (Hulsegge *et al.*, 1997). For the optical probe, the 3/4th last rib was the most used to predict carcass lean (Daumas *et al*, 1998; Ministère des classes moyennes et de l'agriculture, 1999; Hulssege *et al*, 1999). With ultrasonic devices, according to the literature, there is no general agreement on the probing site to predict carcass lean. According to some authors, the last rib was the best site to predict carcass composition in live pig (Diestre, Kempster, 1985; Busmann *et al*, 1991; McLaren *et al*, 1991; Smith *et al*, 1992; Dourmad *et al*, 2001). In other studies, the tenth rib was the most accurate probing site to predict carcass composition (Forrest *et al*, 1989; Gresham *et al*, 1992; Moeller *et al*, 1998). Associations between several probing sites could give better accuracy for the prediction of the carcass composition in live pig (Daumas *et al*, 1998).

[1] RSD = residual standard deviation
C(p)= Mallows'coefficient (Mallows, 1973)

3. CONCLUSION

Several authors have previously used the tenth or the last rib site to predict carcass measurements with real-time ultrasound devices. In this study, the last rib was the best site for carcass lean percentage estimation in Piétrain using ultrasonic device Pie Medical scanner 200. The ultrasound technology could be an accurate tool for selection of breeding stock and a best marketing tool to estimate carcass traits of market pigs when the choice of probing site is clearly defined.

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