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Evaluation of carcass composition of intact boars using linear measurements from performance testing, dissection, dual energy X-ray absorptiometry (DXA) and magnetic resonance imaging (MRI)

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ABSTRACT

The objective of this study was to investigate non-invasive imaging methods to update the used regression equation for stationary tested boars. A total of 94 boars were examined. 20 boars were dissected to provide the reference LMP. Performance data (PD) from right carcasses were available from all groups. The left carcasses were studied by MRI & DXA. Based on the reference LMP and the MRI & DXA data, regression equations for LMP were developed. The estimates for LMP based on MRI & DXA data were used to calculate new regression equations for entire male carcass halves based on linear PD. Further 33 PD sets served as independent sample, which was included in a Monte Carlo simulation for imputing the missing reference LMPs (n = 74) and discussing the accuracy of the results. The LMP regression equation based on the combined MRI & DXA data is as accurate as the former regression equation, but needs only three instead of seven variables.

1. Introduction

Piglet castration without anaesthesia will be banned in Germany (Europe) after 2018. This fact lets boar fattening become an attractive alternative, again. In this context, the accuracy and transferability on entire male carcasses of the regression equations (*Bonner Formula*), which currently are usually used to predict the lean meat percentage of gilts and barrows in stationary performance testing, are discussed. Investigations of boar carcasses showed that the body composition of an intact boar is significantly different than that of barrows or gilts (Bauer, 2010; Dobrowolski, Höreth, & Branscheid, 1995). Dobrowolski et al. (1995) described 6% more lean meat, 8% less fat and increased bone mass in boars. Similar results were achieved by Bauer (2010). There is a shift in body proportions into the front half of the body, leading to muscle growth, especially in the shoulder and belly. In this context the chop is only slightly affected (Ender, Lieberenz, Siegl, & Steinberg, 1987; Walstra, 1974; Walstra, 1980). Especially the shift of muscle proportions into the front body section and the "non-participation" of the chop could lead to an underestimation in the usual classification of carcasses and thus impairment of boar carcasses (Dobrowolski et al., 1995). Therefore it could be possible that an adapted formula considering the altered body proportions of boars is required for performance testing purposes.

The reference method for evaluating meat and fat contents of a carcass is dissection. In general, dissection of carcasses is used as a reference trait for the evaluation of new estimation formulas for lean content. However, dissection is an invasive, expensive, and labour-intensive method. There is a need to focus on methods which can display these muscle and fat contents directly without using dissection. Possible methods are ultrasound (US), computer tomography (CT), magnetic resonance imaging (MRI) and dual energy X-ray absorptiometry (DXA). Out of these methods, MRI is very promising for quantifying muscle and fat tissues, because of its high soft tissue resolution and the three dimensional image information. In many studies, MRI has been used successfully *in vivo* to establish the body composition of pigs, water fowl, poultry, and sheep (Mitchell, Wang, Rosebrough, Elsasser, & Schmidt, 1991; Mitchell, Scholz, & Pursel, 2001; Baulain, 1997; Kremer, Förster, & Scholz, 2013). Fewer studies dealt with MRI at chilled probands (Baulain, Friedrichs, Höreth, Henning, & Tholen, 2010; Collewet et al., 2005; Griep, 1991; Monziols et al., 2006). These authors took into account that MRI could be used instead of dissection. But the use of MRI at chilled probands is difficult, because of physicochemical changes like fat crystallisation and water loss. With the usual used spin echo sequence it is not possible to measure crystallised protons by MRI. In order to scan chilled material, it is necessary to choose a

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Table 1
Bonner Formula (version 2004) with independent variable, intercept and slope.

Dependent variable	Intercept	Slope	Independent variable
Bonner Formula	59.704	−0.147	Back fat area [cm^2]
(2004)		+0.222	Loin eye area [cm^2]
Lean Meat %		−1.744	Back fat lumbar [cm]
LM_{BF}		−1.175	Back fat middle [cm]
		−0.809	Back fat withers [cm]
		−0.378	Side fat [cm]
		−1.801	*Speckmaß B* [cm]

gradient echo sequence which can display these crystallised protons (Monziols et al., 2006; Wehrli, Perkins, Shimakawa, & Roberts, 1987).

Additionally, DXA can be used to evaluate the body composition *in vivo* and on carcasses with a high accuracy (Mitchell, Scholz, Pursel, & Evock-Clover, 1998; Mitchell, Scholz, Wang, & Song, 2001; Mitchell, Scholz, & Pursel, 2003; Scholz, Soffner, Littmann, Peschke, & Förster, 2002; Suster et al., 2003; Marcoux, Faucitano, & Pomar, 2005; Scholz & Förster, 2006; Lösel et al., 2010; Kremer, Fernández-Fígares, Förster, & Scholz, 2012). It performs a whole body scan or can be used for a two dimensional virtual dissection with results for the amount or percentage of total or regional fat tissue, soft lean tissue and bone mineral content as well as bone mineral density (Mitchell, Scholz, & Pursel, 2002; Scholz, Mitchell, Förster, & Pursel, 2007).

The objective of this study was to investigate non-invasive imaging methods as a tool to update regression equations for evaluating the lean meat content during performance testing. In actuality, the performance test formula (*Bonner Formula*) is based on — and was made for — gilts and barrows (Tholen, Wiese, Baulain, Höreth, & Hoppenbrock, 2003, 2004). Therefore, the *Bonner Formula* might not be suitable for intact boars, potentially. The data set for the *Bonner Formula* (Table 1) included 202 fully dissected pigs (n = 19 female Piétrain — Pi; n = 18 male German Landrace; n = 18 male German Large White; n = 37 male Pi × F1 sow line; n = 37 female Pi × F1 sow line; n = 36 female F1 boar line × F1 sow line; and n = 37 male F1 boar line × F1 sow line). The accuracy (RMSE, %) of these measurements was determined as follows: Pietrain: 1.57; sow lines: 1.72; Crossbred I: 2.20; Crossbred II: 2.29 (Tholen et al., 2003, 2004). Since then, the *Bonner Formula* (2004) serves as a standard formula for the estimation of the carcass lean meat percentage during progeny/performance testing in Germany (Standard protocol for stationary performance testing of fattening, 2007).

Dissection, however, still serves as a gold standard to identify differences regarding the lean meat percentage, but is a tedious and costly method. Alternatively, non-invasive methods could be used as reference if they achieve similar accuracies as the gold standard. To determine the body composition in this study – besides dissection, three different procedures were used to calculate the lean meat percentage: MRI, DXA, and linear performance test traits, which were measured according to the standard protocol for performance testing in Germany (Standard protocol for stationary performance testing of fattening, 2007).

2. Material and methods

2.1. Animals

In totality 94 entire male pig carcasses were analysed in a type of extended double sampling procedure. These 94 boars belong to three small random groups out of the station tested pigs in Germany: group 1 (n = 20; originating from performance test station I), group 2 (n = 41; originating from performance test station II & III) and group 3 (n = 33; originating from performance test station IV). The 20 right carcass halves of group 1 were completely dissected into the main body tissues lean meat, fat, and bone and therefore providing the real lean meat content (%) as a reference. In addition to MRI and DXA scanning, linear performance test data were recorded at the left carcass half. For group 2, linear performance test data, as well as MRI and DXA data were available.

In addition, group 3 was used as the independent sample by using the linear performance test data from progeny testing, which were only available for this data set. All boars were F1 crossbreds with Piétrain as sire line and a) crossbred sows from Landrace and Large White or b) crossbred sows from Landrace, Large White, and Leicoma as dam lines. The boars were housed in single pens or in groups of 22 pigs, and fed *ad libitum* with a station specific diet. After gaining the intended slaughter weight, all boars were slaughtered in an abattoir connected to each specific test station. Table 2 shows the mean slaughter weights, linear performance test traits, and the number of animals within the performance test stations (I, II, III, and IV). The reference lean meat percentage from dissection is available alone for station I (group 1) with an average of 60.94 ± 2.44% (n = 20).

2.2. Performance testing

After the boars were slaughtered and weighed, they were split in the middle of the vertebral column and prepared in a uniform manner. Afterwards, linear measurements were performed on the right carcass half according to the standard protocol for performance testing in Germany (Standard protocol for stationary performance testing of fattening, 2007). The following linear carcass measurements were collected at the test stations for each boar (groups 1–3):

- meat and fat area [cm^2] of the chop (loin eye area and above fat layer area), recorded between the 13th and 14th thoracic vertebrae
- side fat thickness [cm] measured *ventral* to the *Musculus latissimus dorsi* perpendicular to the rind between the 13th and 14th thoracic vertebrae, which represents the largest meat-free fat length
- *Speckmaß B* [cm] determined on the chop angle describing the thinnest part of the fat pad between the 13th and 14th thoracic vertebrae
- back fat thickness, specified as an average of three measured fat thicknesses: including the fattest fat thickness at the withers, the thinnest fat thickness in the middle of the back and over the lumbar muscles.

Table 2
Number of animals, mean slaughter weights, and linear performance test traits; by test station (I, II, III, IV).

Test station	n	Slaughter weight [kg]	Loin eye area [cm^2]	Fat area [cm^2]	SFT [cm]	BFT [cm]	*Speckmaß B* [cm]	BFL [cm]	BFW [cm]
I	20	87.02 ± 6.36	51.64 ± 4.75	12.55 ± 2.31	2.11 ± 0.33	1.51 ± 0.20	0.83 ± 0.20	0.75 ± 0.23	2.87 ± 0.35
II	21	91.68 ± 5.19	53.01 ± 4.24	16.40 ± 2.09	2.51 ± 0.45	1.50 ± 2.22	1.12 ± 0.17	1.06 ± 0.27	3.05 ± 0.34
III	20	90.48 ± 5.88	54.14 ± 4.68	14.62 ± 2.69	2.35 ± 0.48	1.39 ± 0.37	0.94 ± 0.25	0.97 ± 0.24	3.14 ± 0.47
IV	33	93.36 ± 3.34	46.77 ± 7.35	12.87 ± 2.76	2.82 ± 0.48	1.71 ± 0.32	0.84 ± 0.17	1.26 ± 0.21	3.50 ± 0.38
All	94	91.02 ± 5.52	50.77 ± 6.40	13.96 ± 2.90	2.50 ± 0.52	1.55 ± 0.30	0.92 ± 0.22	1.04 ± 0.30	3.19 ± 0.45

n = number of animals; SFT = side fat thickness; BFT = back fat middle thickness; BFL = back fat lumbar; BFW = back fat withers.
Group 1 = test station I; group 2 = test stations II & III; group 3 = test station IV.