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RELATIONSHIP BETWEEN CARCASS LEAN MEAT PERCENTAGE AND MRI DATA OBTAINED ON HAMS OF ENTIRE BOARS

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ABSTRACT

The study on the relationship between lean meat percentage (LMP) and ham measures assessed by means of magnetic resonance imaging (MRI) was performed on 20 carcasses of entire boars from one performance testing station in Germany. In addition, linear carcass measurements were taken, according to the standard protocol for stationary performance testing, to be used to estimate LMP by the Bonner Formula. Finally, manual dissection was serving as reference, for LMP. The correlations between the true LMP and linear measurements Bonner Formula were medium strong, but not in all cases statistically significant. On the other hand, the correlations between ham data obtained by MRI and reference LMP had stronger and significant correlations. Three new formulas were constructed in order to evaluate the LMP of entire boars. The best prediction ability was found when combining linear measurements with one MRI measure – the widest circumference of the ham (R^2 = 0.67 and RMSEP = 1.395). Interestingly, the proposed equation has variables that can be easily taken; three of them are taken regularly for Bonner Formula estimation and MRI based ham circumference aided to improve the prediction accuracy, a measure that could also be acquired by the simple use of meter or rope.

Key words: pigs, entire boars, lean meat percentage, Magnetic resonance imaging, dissection

1 INTRODUCTION

The assessment of commercial value of pig carcass is a permanent issue in meat industry. It has always been expressed as lean meat percentage (LMP) and this opened a whole area of research aiming at the most accurate prediction of this trait. The most precise assessment of pig carcass composition is obtained by manual dissection which is time consuming, expensive and results in the loss of carcass. The latter drawback of this method can nowadays be overcome by the use of non-invasive techniques as computed tomography (CT) or magnetic resonance imaging (MRI). The latter was shown to be a precise tool for pig body composition estimation (Baulain, 1997; Mitchell *et al.*, 2001; Baulain *et al.*, 2010). Moreover, some results indicated that scanning of the ham alone can be used as a basis for a good prediction of LMP in pig carcasses and this could reduce the cost of scanning (Font i Furnols *et al.*, 2009).

However, due to the speed of modern slaughter lines, LMP is most often assessed by the use of on-line methods.

Most of those are based on measurements taken on the carcass involving various thicknesses of fat layer and muscle depths, although there were some attempts of usage of other independent variables; e.g. fat and muscle surfaces measured at various positions of pig's carcass (Kušec *et al.*, 2014). High correlation of these measure-

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ments with the actual LMP is a critical criterion for their employment.

Bonner formula, developed in Germany for progeny/performance testing of barrows and gilts, is a good example of using highly correlated carcass measurements for LMP prediction (Tholen *et al.*, 2004). However, *Bonner Formula* is still not developed for entire boars. In near future (2019 in EU) the carcasses of entire male pigs will appear more frequent at the slaughter lines which means that an accurate method of their LMP prediction will be needed soon.

The aim of this study is to establish the correlations between LMP in the carcasses of entire male pigs and carcass measurements as well as some MRI data obtained on their hams in order to investigate the possibility of LMP predictions to be used at the slaughterlines.

2 MATERIAL AND METHODS

The present study was carried out on 20 carcasses of entire boars all of them being F1 crossbreds from sire line Pietrain and Landrace x Large White dams. The boars were kept in single pens at one performance test station in Germany, fed *ad libitum* with a station specific diet. After reaching the intended slaughter weight of approximately 110 kg, boars were slaughtered in the abattoir connected to the test station. After slaughter and primary processing of the carcasses, linear measurements on the right carcass side were taken according to the standard protocol (Richtlinie ….., 2007) as follows:

- Loin and back fat area – LA and BFA (cm^2), recorded at the cut between 13th and 14th thoracic vertebrae
- side fat thickness – SF (cm), measured ventral to the *Musculus latissimus dorsi* perpendicular to the rind between the 13th and 14th thoracic vertebrae
- Backfat thickness, specified as an average of three measured fat thicknesses (the fattest at the withers – BFW, the thinnest in the middle of the back – BFM, and the one over the lumbar muscles – BFL)
- *Speckmaß* B – SMB (cm), determined at the chop angle describing the thinnest part of the fat pad between 13th and 14th thoracic vertebrae

These measures were used for LMP prediction in the pig carcasses using the *Bonner Formula*, as the performance test protocol prescribes.

MR imaging (MRI) of the hams was performed using a Siemens Magnetom Open tomograph which is an open low-field magnetic system with field strength of 0.2 T. Transverse sections were acquired using following parameters: repetition time 700 ms, echo time 17 ms, 7 mm slice thickness, 0.7 mm distance between slices, 18 slices, flip angle of 90°, 458 mm field of view, 256*256 matrix size and 1 accumulation. The sequence was positioned vertical to the *femur* to cover the surrounding muscles. By the use of MRI following traits of the ham were obtained: widest circumference of the ham – CIRC (mm), surface of slice at the widest circumference – SURF (cm^2), estimated ham volume – estV (mm^3), volume of the muscles in ham – hamM (mm^3), volume of the fat in ham – hamF (mm^3).

Finally, the right carcass sides were submitted to the total dissection into the main tissues: muscle (lean meat), fat, and bone, providing the actual lean meat percentage (LMP) as a reference.

Statistical analysis was performed with statistical program Dell Statistica (data analysis software system), version 12. software.dell.com (Dell Inc. 2015); modules Basic Statistics and Tables – Correlation matrices and module Multiple Regression. The full cross validation procedure and graphs were made by CAMO Software AS, NedreVollgate 8, N-0158 OSLO, Norway.

Table 1: *Descriptive statistics for measures used in Bonner Formula for carcass assessment and their correlation with LMP*

Variable	Mean	Standard Deviation	Correlation to LMP
Lean meat percentage, LMP (%)	60.94	2.44	-
Back fat area, BFA (cm^2)	12.55	2.31	−0.53*
Loin area, LA (cm^2)	51.65	4.75	0.66*
Side fat, SF (cm)	2.11	0.33	−0.57*
Back fat whiters, BFW (cm)	2.87	0.35	−0.33
Back fat middle of the back, BFM (cm)	1.51	0.20	−0.30
Back fat lumbar, BFL (cm)	0.75	0.23	−0.52*
Speckmass B, SMB (cm)	0.83	0.20	−0.63*

* marked correlations are statistically significant ($p < 0.05$)

3 RESULTS AND DISCUSSION

Linear carcass measures used as predictors in *Bonner Formula* and their relationship with true LMP obtained by dissection are presented in Table 1.

It is obvious that backfat measures, BFW and BFM, are not significantly correlated with true LMP. This is not making them the best choice as predictors of LMP in the carcasses of entire male pigs used

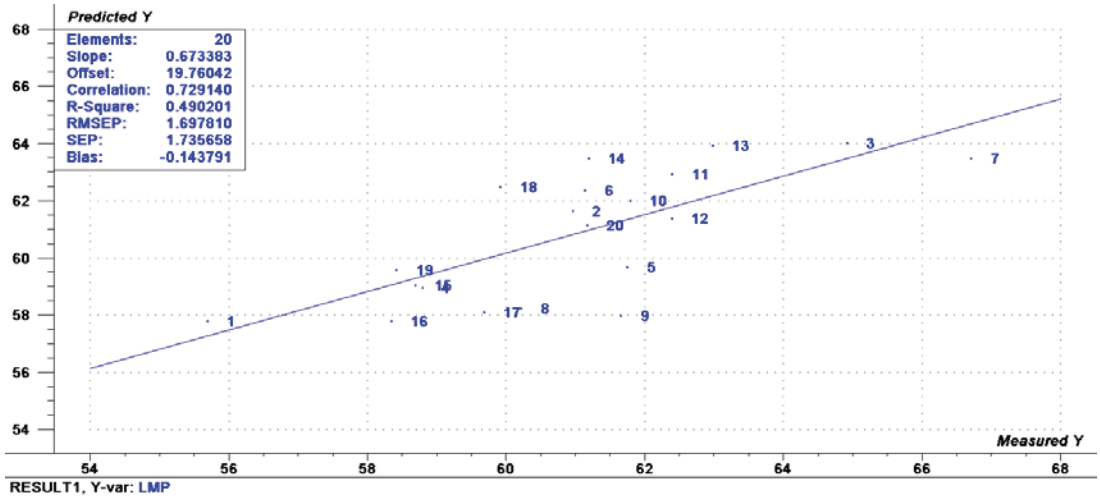

Figure 1: *LMP prediction in the carcasses of investigated entire boars by a new formula based on all variables used in the Bonner Formula*

in this study. Just for illustration, on the basis of 20 boar carcasses investigated in this study, a new formula for the prediction of LMP was derived:

$$LMP = 52.51639 - 0.377 * BFA + 0.327 * LA - 3.825 * BFL - 1.721 * BFM + 1.309 * BFW - 1.519 * SF + 1.437 * SMB$$

The regression of LMPs predicted by this equation on actual LMP obtained by the dissection of entire boar carcasses is shown in Figure 1. Parameters indicating the accuracy of LMP prediction had favourable values, particularly coefficient of determination (R^2) and root mean square error (RMSEP) which were in present case 0.49 and 1.70, respectively.

On the other hand, data obtained by MR imaging of the hams have shown stronger correlations, all being significant, with the LMP obtained by dissection of the carcasses used in this study (Table 2).

Such strong correlations make these measurements good predictors of LMP in the carcasses of investigated entire boars. Regression equation constructed for LMP prediction in this case was:

$$LMP = 61.60681 - 0.04174 * CIRC + 0.00091 * SURF - 0.00151 * estV + 0.00323 * hamM - 0.01499 * hamF$$

The prediction of the LMP in the carcasses of investigated entire boars by this formula is presented on Figure 2.

Prediction capacity of the formula constructed by the use of MRI measurements as independent variables was improved in respect to a new formula derived from the variables used in the *Bonner Formula.* This is apparent from the increased values of R^2 (0.67) which explains the total variation of the actual LMP and lowered RMSEP (1.359) indicating an error of the prediction.

A search for the different new measures that could improve the accuracy of LMP prediction are of permanent interest of researchers. The variety of investigating approaches in this matter is wide, from measuring surfaces of fat and muscle at specific places by MRI like Kremer *et al.* (2013) to pure drawing on transparent paper as performed by Kušec *et al.* (2014).

MRI technique is usually not feasible for the routine assessment of LMP, but measurement such as widest circumference of the ham, which showed fairly good correlation to LMP as presented here, could also be taken without the use of such expensive method. Such variable could be used in order to improve the accuracy of a more practical LMP formula, instead

Table 2: *Descriptive statistics for traits of ham measured by MRI and their correlation with LMP*

Variable	Mean	Standard Deviation	Correlation to LMP
Lean meat percentage, LMP (%)	60.94	2.44	–
Widest circumference, CIRC (mm)	850.89	27.96	0.60*
Surface at the widest circumference, SURF (mm^2)	43535.77	2946.73	0.70*
Estimated ham volume, estV (mm^3)	5317.93	402.67	0.63*
Muscle volume in ham, hamM (mm^3)	3410.18	258.37	0.82*
Fat volume in ham, hamF (mm^3)	514.02	79.04	−0.53*

* marked correlations are statistically significant ($p < 0.05$)

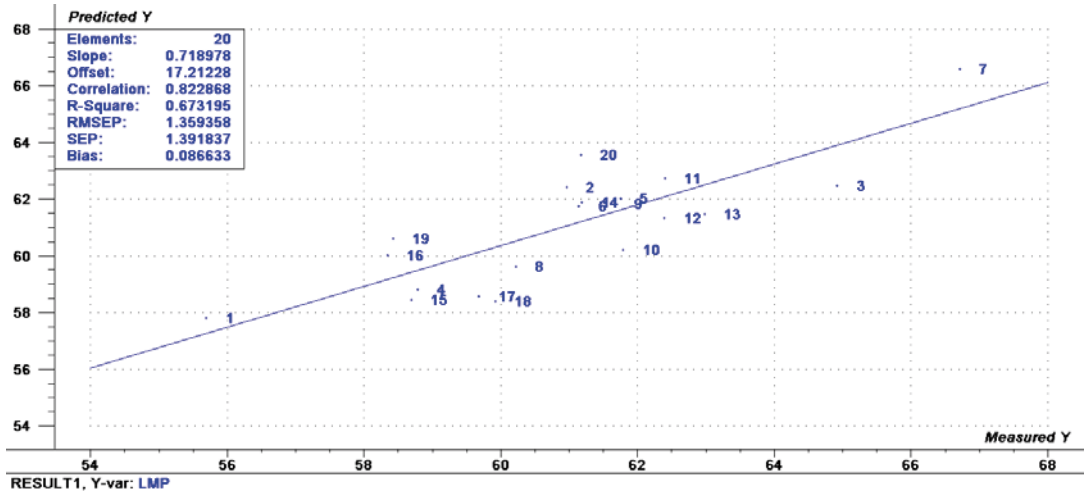

Figure 2: *LMP prediction in the carcasses of entire boars by the equation constructed by use of MRI measurements as predicting variables*

of the variables that showed insignificant correlations with actual LMP obtained by dissection of the boar carcasses. In present study we also attempted to improve the ability of LMP prediction by equations using various combinations of independent variables from *Bonner Formula* and MRI measurements of the ham.

Figure 3 shows the equation that yielded the best indicators of accuracy (R^2 = 0.67 and RMSEP = 1.395). For this equation, only linear measurements taken directly (BFA, LA, BFL) or virtually (CIRC) from the carcass were used, resulting in the following parameters:

$$LMP = 32.34091 - 0.28296 * BFA + 0.23627 * LA - 3.95181 * BFL + 0.02690 * CIRC$$

Of all measurements obtained by the use of MRI, only ham circumference (CIRC) aided in the improvement of predicting ability, but this feature of the ham can be also measured by the simple use of meter or rope.

Attempts to improve the *Bonner formula* to assess carcass lean meat content in entire boars by use of non-invasive methods were made before. Recently, Bernau *et al.* (2015) investigated the use of dual energy X-ray absorptiometry (DXA), magnetic resonance imaging (MRI) and dissection to evaluate the carcass composition; and they also tested the suitability of the *Bonner Formula*.

The authors found that formulas from DXA, MRI and combination of MRI/DXA yielded the same and better accuracies than *Bonner Formula*. However, their result was obtained on the same sample of entire boars' carcasses (n = 20) as in the present study, meaning that these results should be interesting enough to be repeated

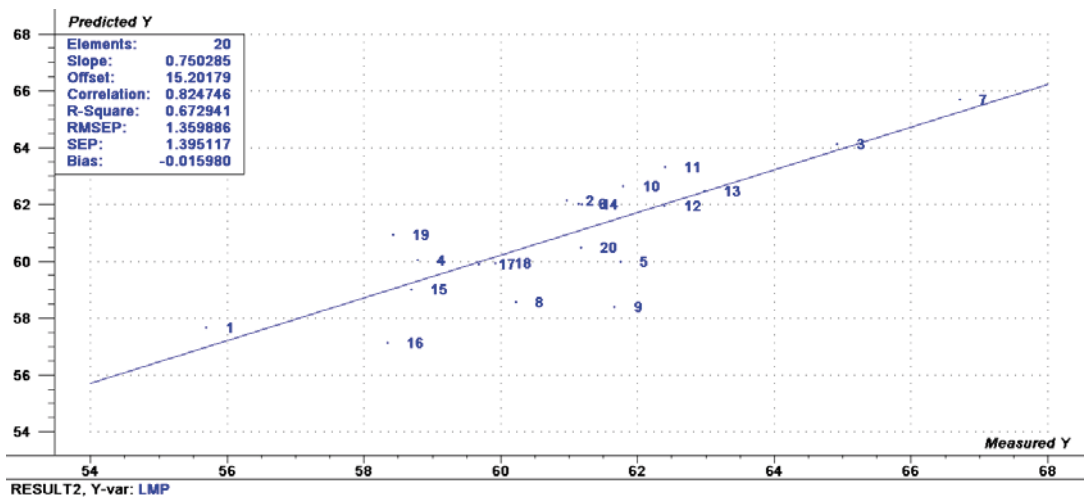

Figure 3: *LMP prediction in the carcasses of investigated entire boars by the adapted LMP formula with MRI measurement of ham circumference as additional predicting variable*

on a larger sample. This can also be stated for the results of the investigations presented here.

4 CONCLUSION

The results from present study show that the measurements such as BFW and BFM were not significantly correlated with the actual LMP, which reduces the acceptability of Bonner *Formula* as method for prediction of LPM in the carcasses of entire boars.

On the other hand, the measures of the ham assessed by MR imaging had stronger and significant correlations with LMP obtained by dissection.

The formula constructed using MRI measurements as independent variables had increased prediction ability in respect to the "new" *Bonner Formula*.

Equation taking into account BFA, LA and BFL measures together with ham circumference obtained by MRI (CIRC) as independent variables, had the best predicting ability.

Since ham circumference can be also measured using meter or rope it could be considered as an interesting predictor for future studies of methods for the prediction of LMP in pig carcasses from entire boars.

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