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Lean meat prediction with HGP, CGM and CSB-Image-Meater, with prediction accuracy evaluated for different proportions of gilts, boars and castrated boars in the pig population

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ABSTRACT

Prediction equations for the percentage lean meat in pig carcasses in The Netherlands were derived for the Hennessy Grading Probe 7, Capteur Gras/Maigre — Sydel and CSB-Image-Meater. Because castrated males are expected to vanish from the Dutch pig population in the near future, accuracy of prediction was evaluated for different scenarios representing a wide range of different proportions for entire males, castrated males and females in the Dutch pig population. The prediction equations for the instruments are in compliance with the EC regulations for prediction accuracy for the different scenarios. So, these equations will remain valid when castrated males are (gradually) removed from the Dutch slaughter population. Results of this study are of interest for researchers from countries or areas contemplating the use of one of the aforementioned instruments. The statistical approach for evaluation of prediction accuracy is of particular interest when changes in proportions of important subpopulations in the target population are foreseen.

1. Introduction

Pig carcass grading, based on instrumental classification, is an incentive to produce pigs of desired quality. Classification is based on the (predicted) lean meat percentage (LMP) in the carcass, as derived from dissection of all striated muscle tissue from the carcass as far as possible by knife (European Community, 2008; Walstra & Merkus, 1995). The LMP is the basis for payment to the producers and for marketing of pig carcasses within the European Community. The LMP can be predicted objectively on-line in slaughterhouses using different kind of devices for taking measurements on the carcass. Devices can be manual, semiautomatic or automatic, and measurements can be derived from light reflectance (FOM, HGP, CGM), ultrasound (UFOM, AUTOFOM), electromagnetism (TOBEC) or vision (VCS2000, CSB-Image-Meater) (Font & Gispert, 2009). Recently computer tomography is considered as an alternative for the rather laborious dissection.

A prediction equation based on objective measurements obtained by a device has to be in compliance with the EC regulations (European Community, 2008) for proper sampling of carcasses for dissection and accuracy of prediction. Guidance and recommendations with respect to the statistical calculations involved is provided in a handbook by Causeur et al. (2006).

In The Netherlands, grading of pig carcasses is carried out with the Hennessy Grading Probe 2 (HGP2) since July 1987. The prediction equation for the percentage lean meat in a pig carcass comprises a fat and a muscle depth, measured by HGP2, as prediction variables. The present prediction equation was established in July 2006 (Engel, Lambooij, Buist, Reimert, & Mateman, 2006). Recently the HGP2 was updated to the Hennessy Grading Probe 7 (HGP7). A pilot experiment suggested that differences between HGP2 and HGP7 were such that a new prediction equation for HGP7 was required.

A dissection experiment was performed that included, in addition to HGP7, two other instruments, the Capteur Gras/Maigre — Sydel (CGM) and the CSB-Image-Meater (CSB). All three instruments were considered potential successors of HGP2. Some technical details of the instruments are provided in the Appendix A. CGM and HGP7 collect a fat and muscle depth measurement at the same location at the carcass as HGP2, i.e. at the third to fourth from last rib position, 6 cm from the dorsal mid line. Since HGP7 and CGM are invasive probes, the measurements had to be taken using the same puncture. The aforementioned pilot experiment confirmed the conclusion in Olsen et al. (2007) that use of the same puncture does not affect the second measurement, neither with respect to the mean nor with respect to the variance. The needle of the CGM is thicker than the needle from HGP7, and each carcass was first measured by the non-invasive CSB, then by HGP7 and finally by CGM.

A change in the Dutch pig population is foreseen: castrated males are expected to be absent in the near future. Therefore, accuracy of prediction was evaluated for different scenarios for the proportions of

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entire males, castrated males and females in the Dutch pig population, including a scenario without castrated males in the slaughter population. For a proper calculation of accuracy of prediction, separate samples of dissected carcasses were needed for entire males, castrated males and females. Carcasses had to be selected during a short time span. For a proper calculation of accuracy of prediction representative samples were needed, i.e. samples that can be treated as if they were random. For that reason, carcasses for dissection were selected on the basis of the HGP7 fat depth measurement. Fat depth classes were formed for the three sexes, with sample proportions of carcasses in these classes equal to associated population proportions. The sampling scheme is close to the scheme that was used by Engel et al. (2006). Details are provided in the material and methods section.

With HGP7 and CGM only two objective carcass measurements are collected, and the prediction equation was derived with (weighted) least squares (Montgomery & Peck, 1992). With CSB, which is a vision system, 16 objective carcass measurements are collected (related to fat and muscle depth and to the length of the carcass), and the prediction equation was derived with partial least squares (PLS) (Brown, 1993). In addition, for CSB, the performance of principal component regression (PCR) (Brown, 1993), and linear regression with variable selection (subset selection) (Montgomery & Peck, 1992) was studied as well.

The aim of this paper is to present (1) prediction equations for HGP7, CGM and CSB, and (2) an evaluation of the accuracy of prediction of these equations under different scenarios for the proportions of entire males, castrated males and females in the Dutch pig population. The first aim is of obvious interest for researchers considering the use of HGP7, CGM, or CSB in a region or country. The second aim is of interest for researchers who need to derive a prediction equation, while changes in proportions of important subpopulations (here the sexes) in the target population are expected.

2. Material and methods

2.1. Sampling and accuracy of prediction, preliminaries

The accuracy of prediction was evaluated in terms of the root mean squared error of prediction (*RMSEP*), employing leave-one-out, in accordance with the EC regulations (European Community, 2008) and the statistical handbook for pig grading (Causeur et al., 2006). For evaluation of the *RMSEP* for different scenarios for the proportions of the sexes in the population, a separate sample was needed for entire males, castrated males and females from the Dutch population of slaughter pigs. For a proper interpretation of the *RMSEP*, these samples needed to resemble random samples of carcasses for the three sexes.

Collection of a truly random sample of carcasses is extremely difficult, because practical limitations often do not allow sampling of carcasses from all slaughterhouses in a country or region and throughout the year. Therefore, within the limited time span of the experiment, proportional samples were taken. A proportional sample mimics a random sample. A sample of 40 carcasses was taken for castrated males and samples of 60 carcasses were collected for entire males and for females. This way, without the castrated males, the sample size was still equal to 120 dissected carcasses, the minimum sample size as required by the EC regulations (European Community, 2008).

Carcasses were sampled from four Dutch slaughterhouses. These were large slaughterhouses that covered the different breeds in the Netherlands. Carcasses with carcass weight outside the range from 73.5 to 107.5 (kg) were not included to avoid the truly unusual carcasses. Slaughter pigs were all transported to one of the slaughterhouses, where the instruments were installed. Carcasses were selected in the slaughterline and dissected one day after slaughter according to the EU reference dissection method (Walstra & Merkus, 1995). After dissection the EC reference lean meat percentage (European Community, 2008, Annex IV, Section 2) was calculated.

2.2. Selection on HGP7 back fat

The HGP7 fat depth measurement was used for selection of the carcasses in the slaughterline. For entire males, castrated males and females each, five classes were defined based on the HGP7 fat depth measurement. Boundary values for these classes were based on a very large sample of representative slaughterhouse data, comprising fat depth measurements with the HGP2 probe and gender. Initially, the 9, 29, 71 and 91% percentile points for HGP2 fat depth for each of the sexes were determined as boundary values. Since use of HGP2 would require a third measurement using the same puncture, HGP2 was not used for selection, but boundary values for HGP2 were transformed into boundary values for HGP7. This was achieved by linear regression (Montgomery & Peck, 1992) of HGP7 upon HGP2 fat depth measurements, based on a large sample of carcasses that were measured by both instruments in the aforementioned pilot experiment.

The intended numbers of carcasses in the HGP7 back fat classes are reproduced in Table 1. The samples of dissected carcasses were proportional, e.g. we intended to have 5 (about 9% of 60) carcasses in the lowest fat class for entire males, 12 ($5+12=17$ is about 29% of 60) in the one but lowest fat class, etc. The boundary values for HGP7 back fat used for entire males were 12.2, 14.1, 16.4 and 18.7 (mm), for castrated males 14.1, 16.0, 19.1 and 22.2 (mm), and for females 12.2, 14.1, 17.2 and 19.5 (mm). Due to some unforeseen problems, the actual numbers that were realized (in parentheses in Table 1) were nearly, but not quite the same as the intended numbers. The total sample size was 160 carcasses.

Some summary statistics of the dissected carcasses are presented in Tables 2a and 2b.

2.3. Weighted least squares for HGP7 and CGM

Separate samples were collected for the three sexes, in order to evaluate the accuracy of prediction for different scenarios for the proportions of the sexes in the population. However, we did not intend to use separate prediction equations in the slaughterline for the sexes. For each of the probes HGP7 and CGM, a single overall prediction equation was derived for all three sexes together. The equation was calculated for equal representation of the sexes, but prediction accuracy was also evaluated for other scenarios for the proportions of the three sexes. The following weighted sum of squares was minimized, where the inverses of the sample sizes (n_i) for the sexes were included as weights, to correct for the unequal numbers of the sexes in the sample:

$$\frac{1}{3}\sum_{i=1}^{3}\frac{1}{n_i}\sum_{j=1}^{n_i}\left(y_{ij}-\hat{y}_{ij}\right)^2$$

Table 1
The numbers of carcasses in HGP7 back fat classes per sex. Fat classes are numbered 1…5, boundary values for entire males, castrated males and females are presented in the text. Intended numbers of carcasses, and actual numbers (in parentheses) are shown.

HGP7 fat class		Entire males		Castrated males		females	
Low HGP7 fat	1	5	(5)	3	(3)	5	(5)
	2	12	(13)	8	(8)	12	(12)
	3	26	(25)	18	(17)	26	(27)
	4	12	(12)	8	(9)	12	(11)
High HGP7 fat	5	5	(5)	3	(3)	5	(5)
Total sample size		60	(60)	40	(40)	60	(60)