**Precision livestock farming: real-time estimation of daily protein deposition in growing-finishing pigs**

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Supplementary Table S1 Descriptive statistics of the dataset (78 barrows) used to calibrate the equations estimating total body protein and protein deposition over the growing-finishing period*.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Item | Number of observations | Mean | SD1 | 1% quantile | 99% quantile | Min. | Max. |
| Body weight (kg) | 312 | 84.50 | 34.29 | 28.99 | 144.12 | 26.66 | 149.30 |
| Body protein mass (kg) | 312 | 15.25 | 5.26 | 5.91 | 23.95 | 5.46 | 26.54 |
| Body lipid mass (kg) | 312 | 15.84 | 12.74 | 1.47 | 44.87 | 1.29 | 46.85 |
| Protein deposition (g/d)1 | 234 | 158.84 | 38.94 | 84.34 | 233.64 | 69.97 | 243.92 |
| Protein content in weight gain (%) | 234 | 14.47 | 2.92 | 8.89 | 20.01 | 6.98 | 20.85 |
| Gain:Feed | 234 | 0.39 | 0.08 | 0.26 | 0.59 | 0.24 | 0.62 |
| Average daily feed intake (Kg/d) | 234 | 2.89 | 0.52 | 1.78 | 4.07 | 1.75 | 4.27 |

**1** Rate variables (e.g. protein deposition) differ in number of observations from the state variables (e.g. body weight) because they are calculated as the average (difference from the final condition to initial condition) per pig over the three growing periods studied. SD= Standard deviation

Supplementary Table S2 Descriptivestatistics of the dataset (365 pigs1) used to validate the equation to estimate body protein mass and protein content in weight gain*.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Item | Number of observations | Mean | SD | 1% quantile | 99% quantile | Min. | Max. |
| Body weight (kg) | 751 | 66.87 | 37.58 | 23.31 | 144.61 | 20.95 | 154.72 |
| Body protein mass (kg) | 751 | 10.82 | 5.93 | 3.38 | 22.34 | 2.89 | 23.17 |
| Body lipid mass (kg) | 751 | 11.074 | 9.94 | 3.77 | 39.93 | 3.67 | 47.52 |
| Protein deposition (g/d) 2 | 365 | 161.27 | 33.47 | 94.60 | 225.41 | 54.12 | 233.99 |
| Protein content in weight gain (%) | 355 | 16.16 | 3.90 | 5.94938 | 21.34 | 4.52 | 22.78 |

1 365 pigs with two dual x-ray measurements per pig and 21 pigs with one measurement.

**2** Rate variables (e.g. protein deposition) differ in number of observations from the state variables (e.g. body protein) because they are calculated as the average (difference from the final condition to initial condition) per pig over the three growing periods studied.

SD= Standard deviation

Supplementary Table S3. Descriptive statistics of the calibration for the Gompertz curves used to estimate body protein and deposition in pig populations*.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Estimated Parameters** | | | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |
| **Model1** | **a** | **b** | **c** | **RE** | | **GrA** | | **GrC** | | **GrB** | | **GrAB** | | **GrCB** | | **AIC** | | **RSD** | | **R2** | | **MSPE** | | **RMSE** | | **Coef. Conc.** | **Bias prop.** |
| **Model 1** | 29.81 | 2.41 | 0.02 | 0.41 | |  | |  | |  | |  | |  | | 615.00 | | 5.200 | | 0.985 | | 0.410 | | 0.636 | | 0.993 | 0.003 |
| Model 1 SE | 0.68 | 0.03 | 0.001 | 0.03 | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  |  |
| **Model 2  a random** | 29.14 | 2.43 | 0.16 | 0.13 | | 0.89 | |  | |  | |  | |  | | 438.60 | | 5.300 | | 0.996 | | 0.103 | | 0.321 | | 0.998 | 0.001 |
| Model 2 SE | 0.35 | 0.0012 | 0.0003 | 0.01 | | 0.06 | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  |  |
| **Model 3 c random** | 30.17 | 2.40 | 0.02 | 0.17 | |  | | 0. 39E-6 | |  | |  | |  | | 487.90 | | 5.200 | | 0.995 | | 0.134 | | 0.363 | | 0.998 | 0.004 |
| Model 3 SE | 0.41 | 0.02 | 0.00 | 0.02 | |  | | 0 | |  | |  | |  | |  | |  | |  | |  | |  | |  |  |
| **Model 4  a and b random** | 28.78 | 2.44 | 0.02 | 0.11 | | 2.16 | |  | | 0.00399 | | 0.12 | |  | | 347.00 | | 5.200 | | 0.995 | | 0.129 | | 0.359 | | 0.998 | 0.061 |
| Model 4 SE | 0.33 | 0.02 | 0.0003 | 0.01 | | 0.39 | |  | | 0.00175 | | 0.02 | |  | |  | |  | |  | |  | |  | |  |  |
| **Model 5  a , b and c random** | 28.79 | 2.43 | 0.02 | 0.13 | | 0.02 | | 0. 47E-6 | | 0.00171 | | 0.12 | | -0.1E-4 | | 403.00 | | 5.200 | | 0.995 | | 0.410 | | 0.634 | | 0.993 | 0.003 |
| Model 4 SE | 0.52 | 0.02 | 0.001 | 0.02 | | 1.95 | | . | | 0.00634 | | 0.08 | | 0.0001 | |  | |  | |  | |  | |  | |  |  |

Note:Convergence criterion was satisfied for all models.

1 Abbreviations: SE= Standard Error; RE= Residual Error; GrA= variance of the parameter a; GrC= variance of the parameter c; GrB= variance of the parameter b; GrAB= covariances between a and b; GrBC= covariances between b and c. AIC= Akaike information criterion; MSPE= Mean squared prediction error; RMSE= Root Mean Square Error; R2= Coefficient of determination; RSD= relative standard deviation; coef. Conc= Coefficient of concordance; Bias prop.= Proportion of bias.

Supplementary Figure S1

|  |  |
| --- | --- |
| a) |  |

Supplementary Figure S1. Model validation for prediction of (a) body protein mass (kg) as function of body weight using either the linear-quadratic (Lin-Quad) regression or the Gompertz function, and (b) model validation to predict the percentage of protein deposition in weight daily gain (PD/DG) as a function of body weight in pigs.

Supplementary Table S4. Estimated by regression body weight (BW), and average daily gain (ADG), and estimated protein deposition (PD) obtained with either the Linear-Quadratic regression (Lin-Quad) or Gompertz (Gomp.) curve and compared to the original model proposed by Hauschild et al., (2012) in pigs. Accuracy of the models was evaluated by the mean absolute prediction error (MAPE, %).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Estimated** | | | | |  | | **Observed** | | |  | | **MAPE (%)** | | | |
| **Pig number** | **BW (Kg)** | **ADG (g)** | **Lin-Quad PD (g)** | **Gomp. PD (g)** | **Hauschild PD (g)** |  | **BW (Kg)** | | **PD (g)** |  | | **Lin-quad** | | **Gomp.** | **Hauschild (2012)** |
| 8 | 27 | 845 | 169 | 131 | 135 |  | 28 | | 151 |  | |  | |  |  |
| 8 | 54 | 1166 | 206 | 203 | 187 |  | 55 | | 153 |  | |  | |  |  |
| 8 | 87 | 1243 | 182 | 193 | 199 |  | 87 | | 210 |  | |  | |  |  |
| 8 | 118 | 1068 | 127 | 127 | 171 |  | 118 | | 99 |  | |  | |  |  |
| *Average* | *71* | *1080* | *171* | *163* | *173* |  | *72* | | *153* |  | | *22.2* | | *20.5* | *27.5* |
| 22 | 29 | 960 | 189 | 149 | 154 |  | 29 | | 174 |  | |  | |  |  |
| 22 | 61 | 1325 | 226 | 231 | 212 |  | 60 | | 246 |  | |  | |  |  |
| 22 | 98 | 1511 | 211 | 234 | 242 |  | 99 | | 206 |  | |  | |  |  |
| 22 | 139 | 1533 | 160 | 180 | 245 |  | 138 | | 174 |  | |  | |  |  |
| *Average* | *82* | *1332* | *197* | *199* | *213* |  | *81* | | *200* |  | | *6.7* | | *9.5* | *21.0* |
| 80 | 23 | 842 | 170 | 126 | 135 |  | 24 | | 148 |  | |  | |  |  |
| 80 | 51 | 1093 | 196 | 190 | 175 |  | 51 | | 223 |  | |  | |  |  |
| 80 | 85 | 1205 | 181 | 190 | 193 |  | 84 | | 160 |  | |  | |  |  |
| 80 | 118 | 1169 | 143 | 138 | 187 |  | 119 | | 163 |  | |  | |  |  |
| *Average* | *69* | *1077* | *173* | *161* | *172* |  | *69* | | *174* |  | | *13.2* | | *15.9* | *16.4* |
| 16 | 30 | 961 | 189 | 153 | 154 |  | 30 | | 175 |  | |  | |  |  |
| 16 | 59 | 1164 | 200 | 202 | 186 |  | 59 | | 215 |  | |  | |  |  |
| 16 | 93 | 1190 | 171 | 177 | 190 |  | 92 | | 185 |  | |  | |  |  |
| 16 | 125 | 1018 | 119 | 112 | 163 |  | 125 | | 125 |  | |  | |  |  |
| *Average* | *77* | *1083* | *170* | *161* | *173* |  | *76* | | *175* |  | | *6.9* | | *8.4* | *14.7* |
| 73 | 26 | 922 | 184 | 142 | 148 |  | 26 | | 163 |  | |  | |  |  |
| 73 | 56 | 1235 | 216 | 215 | 198 |  | 56 | | 214 |  | |  | |  |  |
| 73 | 92 | 1282 | 185 | 192 | 205 |  | 91 | | 158 |  | |  | |  |  |
| 73 | 125 | 1047 | 122 | 115 | 167 |  | 125 | | 126 |  | |  | |  |  |
| *Average* | *75* | *1122* | *177* | *166* | *179* |  | *74* | | *165* |  | | *8.6* | | *11.0* | *20.0* |
| 90 | 23 | 778 | 157 | 116 | 125 |  | 23 | | 137 |  | |  | |  |  |
| 90 | 49 | 1132 | 205 | 196 | 181 |  | 49 | | 208 |  | |  | |  |  |
| 90 | 81 | 1242 | 190 | 199 | 199 |  | 82 | | 176 |  | |  | |  |  |
| 90 | 114 | 1078 | 135 | 132 | 172 |  | 114 | | 121 |  | |  | |  |  |
| *Average* | *67* | *1058* | *172* | *161* | *169* |  | *67* | | *161* |  | | *9.1* | | *10.9* | *19.4* |
| **Average total** | 74 | 1134 | 178 | 169 | 181 |  | 74 | | 175 |  | | 8.9 | | 11.1 | 18.3 |