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Corrections to prediction of backfat thickness and relationships among model parameters in INRAPORC®

Sebastião Ferreira Magagnin[1*], **Lucélia Hauptli**[2], **Marson Bruck Warpechowski**[3]

[1] Universidade Federal de Santa Catarina, Fazenda Experimental Ressacada, Florianópolis, SC, Brasil.
[2] Universidade Federal de Santa Catarina, Departamento de Zootecnia e Desenvolvimento Rural, Florianópolis, SC, Brasil.
[3] Universidade Federal do Paraná, Departamento de Zootecnia, Curitiba, PR, Brasil.

***Corresponding author:**
sebastiao.ferreira@ufsc.br

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ABSTRACT - We evaluated whether the procedure for correcting backfat thickness (BT) equation coefficients and lipid mass (LM) initial values in animal profiles, as well as actual model parameter (MP) data and their interrelationships, could reduce errors in predicting body weight (BW) and BT in pigs reared in Southern Brazil. Because different combinations of actual and estimated MP values in advanced system calibration mode (ACM) give rise to distinct calibration procedures, their BT and BW prediction errors were compared with those obtained by INRAPORC® default mode calibration based on different parameter combinations. Correlations among MP were also verified. The BT prediction correction (BTcor) procedure reduced the BT standard deviation of the estimate (σ) from 3.25 to 2.42 mm, but the correction had no effect on BW. Actual BT and feed intake data at 50 kg BW (FI50), reported in ACM, reduced prediction errors of BW and BT, in which their σ values were reduced from 5.29 to <4.08 kg and 2.42 to <2.12 mm, respectively. Mean protein deposition (MeanPD), FI50, and feed intake at 100 kg BW (FI100) were strongly and positively correlated (r>0.98). In addition, initial BW (BWi) was strongly negatively correlated with these parameters (r<−0.87) but positively correlated with the maintenance adjustment factor (MAINT) (r = 0.75). The inclusion of actual or default MP values in the ACM strongly influenced the estimation of other values, as well the predicted outcomes for BW and BT. The BTcor procedure and the input of actual or default MP values into the ACM of INRAPORC® is justified to reduce prediction errors, as it yields considerably greater accuracy in a pig nutritional adjustment system.

Keywords: backfat thickness, calibration procedures, lipid correction, nutritional modeling, swine

1. Introduction

INRAPORC® is a tool for elaboration or adjustment of pig nutritional strategies. Using concepts of net energy, ideal protein, and digestible amino acids, the system can predict nutrient transformation from feed into lipids and body proteins, as well as retention and excretion of animal nutritional components (van Milgen et al., 2008). Lipid mass (LM) and backfat thickness (BT) estimates obtained by INRAPORC® had significant systematic errors compared with observed values in commercial pigs in Southern Brazil (Warpechowski et al., 2014). It is possible to improve precision and accuracy of BT prediction by adjusting some BT equation coefficients and initial LM (LMi) values in the animal profile. To obtain parameter values that describe the growth and feed intake potential used thereafter to simulate performances using INRAPORC®, the system must be calibrated in default or advanced mode. Default mode uses observed body weight (BW) data and cumulative feed intake (CFI) from an animal group subject to *ad libitum* (AL) feed management, during the major part of the rearing period. The advanced calibration mode (ACM) allows the additional entry of observed BT values in the system calculation matrix, as well as the entry of the actual values of the model parameters (MP) instead of estimating them through the system calibration (van Milgen et al., 2008). The MP modulate the feed intake and animal weight gain in the system.

Values of MP are interrelated (Brossard et al., 2006; Vautier et al., 2013), such that different combinations of actual, default, and estimated MP values in the INRAPORC® ACM will result in animal profiles with different potential performances. However, actual values of some MP are not readily available on production farms. For example, mean protein deposition (MeanPD), the maintenance adjustment coefficient (MAINT), and the animal growth curve modulating factor (precocity) can only be obtained *in silico* by compiling animal performance data. In contrast, actual values of other MP can be obtained from farms: initial BW (BWi), feed intake at 50 kg BW (FI50), and 100 kg BW (FI100).

We aimed to evaluate whether correction of BT equation coefficients, adjustment of the LMi value in animal profile, and the input of default or actual MP values and actual BT values in INRAPORC® ACM can reduce BW and BT prediction errors and increase its predictive accuracy.

2. Material and Methods

We used a database compiled in 2012 by Pierozan (2014) from an experimental farm in Pinhais, Paraná, Southern Brazil (25°23'29.1" S and 49°08'14.0" W, 937 m altitude). This research was approved (under case no. 016/2012) by the institutional Animal Ethics and Use Committee.

This experiment used data from 12 crossbred barrows aged 128 days, housed in four pens with three animals per pen. These animals had the same genetic origin, coming from the same group of animals on the pig farm, where they received the same management and diet.

A group of six animals with BWi of 74.7±4.6 kg was provided AL feed; data from the AL group were used for calibration purposes. Another group of six animals with BWi of 78.5±4.0 kg was subjected to restricted feed management (RF), receiving an average of 2.7 kg.day^{-1} feed during the entire test period; data from the RF group were used to evaluate the accuracy of BT and BW predictions, and not for system calibration. Data for each individual were collected weekly for 13 weeks, yielding 78 observations per group and 156 observations in total.

The observed BT values from the study by Pierozan (2014) were measured *in vivo* by using a DigiPrice DP3300VET ultrasound, at the position of the last thoracic rib, 65 mm from the dorsal midline, at point P2, on the left and right sides of the animals (Warpechowski et al., 2014). As the system is deterministic in calibrating and verifying the accuracy of BT and BW predictions, weekly averages were used.

We input these data into INRAPORC®, a model and software developed and distributed by the Institut National de La Recherche Agronomique (INRA), which uses the INRA-CIRAD-AFZ (Centre de Coopération Internationale en Recherche Agronomique pour le Développement - Association Française de Zootechnie) feed database (version 1.6.5.7).

An original system calibration procedure and a BT prediction correction (BTcor) procedure were verified. System calibration required information on dietary nutritional levels, CFI, and BW data from the AL group. For the original calibration procedure, a 100% AL feed allowance plan and a single diet plan was used. Information on dietary composition was estimated by the system based on a previously established dietary formulation (Table 1), as the system does not formulate diets. Ingredient composition information was obtained from the INRAPORC® database and nutrient composition was calculated by the system (Table 2). In the animal profile, options chosen for AL intake were megajoules of net energy.day^{-1} and the gamma equation (maintenance); CFI and BW mean data of the AL group were entered into the system calibration matrix, and the default INRAPORC® calibration mode was selected for the Original (0^{DC}) system calibration procedure (Table 3). This calibration procedure, after the BTcor procedure described below, becomes the corrected calibration procedure (1^{DC}). The BTcor

Table 1 - Dietary formulation used in the INRAPORC® calibration, extracted from Pierozan (2014)

Dietary component	Composition (g/kg)
Milled corn	775.23
Soybean meal	194.00
Mineral vitamin premix[1]	30.00
L-Lysine	0.77
Total	1000.00

[1] Mineral-vitamin premix composition per kilogram: vitamin A, 80,000 IU; vitamin D_3, 26,500 IU; vitamin E, 320 IU; vitamin K_3, 75 mg; vitamin B_1, 16.7 mg; vitamin B_2, 90 mg; vitamin B_6, 16.7 mg; vitamin B_{12}, 500 mg; niacin, 500 mg; calcium pantothenate, 250 mg; folic acid, 15 mg; choline chloride, 1200 mg; NaCl, 60 g; Fe, 1667 mg; Cu, 2500 mg; Mn, 800 mg; Zn, 1500 mg; I, 33.4 mg; Se, 8.35 mg; $C_{amin/max}$, 80/180 g; P, 10 g; phytase, 16667 FTU; zinc bacitracin, 1333.34 mg.

Table 2 - Nutrient composition of diet as fed and analyzed[1] and calculated by the INRAPORC® model[2]

Nutrient composition	Analyzed[3]	Calculated
Dry matter (%)	88.01	87.05
Metabolizable energy (Cal/g)	-	3217.00
Gross energy (Cal/g)	3811.00	3826.00
Mineral residue (%)	4.56	4.52
Organic matter (%)	83.45	82.53
Ethereal extract (%)	3.06	3.20
Crude protein (%)	15.52	14.75
Crude fiber (%)	2.77	2.89
Neutral detergent fiber (%)	17.84	10.47
Acid detergent fiber (%)	4.16	3.45
Lignin (%)	0.56	0.47
Calcium (%)	0.54	0.34
Total phosphorus (%)	0.30	0.35
Digestible phosphorus (%)	0.24	0.12
Phytic phosphorus (%)	-	63.50
Sodium (%)	0.19	0.18
Potassium (%)	0.51	0.66
Net energy of INRAPORC (MJ NE/kg)[4]	10.20	10.27

[1] Analyzed nutrient content (dry matter basis).
[2] Values estimated by the INRAPORC® model, based on the feed formulation and nutrient composition from ingredient tables of the French Association of Zootechnics (AFZ).
[3] Values from Pierozan (2014).
[4] Energy density of diets obtained by the INRAPORC® diet module.

Table 3 - Calibration modes, dependent variables of the calibration curve, and actual or default model parameter input values in advanced calibration mode for each INRAPORC® calibration procedure

Calibration procedure	Calibration mode	Animal profile calibration module	
		Dependent variables of calibration curve	Model parameters with actual or default input values in calibration mode[1]
0[DC]	Default	CFI/BW	MAINT[d]
1[DC]	Default	CFI/BW	MAINT[d]
2	Advanced	CFI/BW/BT	NONE
3	Advanced	CFI/BW/BT	MAINT[d]
4	Advanced	CFI/BW/BT	FI50[a]
5	Advanced	CFI/BW/BT	FI50[a]/BWi[a]
6	Advanced	CFI/BW/BT	MAINT[d]/FI50[a]
7	Advanced	CFI/BW/BT	MAINT[d]/FI50[a]/BWi[a]

CFI - cumulative feed intake; BW - body weight; BT - backfat thickness; MAINT - maintenance adjustment coefficient, default value set at 1.00; FI50 - feed intake by the animal at 50 kg body weight; BWi - initial body weight; NONE - all model parameters were estimated by the system.
[1] Actual values were obtained on farm or in laboratory calculations, whereas the default values were system defaults, without manual alteration. These values were set in advanced calibration mode. In default calibration mode ([DC]) the value of the maintenance adjustment coefficient (MAINT) was the only one already set.
[a] Actual input value.
[d] Default input value.

procedure is divided into two steps: the first corrects BT equation coefficients and recalibrates the system (BTc1) and the second corrects the LMi value for the RF animal profile (BTc2).

The BTc1 step: in the system settings module, the BT equation represents the linear relationship between LM and BT (Equation 1). By default, the values of their coefficients are "a" = 6.960 and "c" = 0.375.

$$BT = c * (LM) + a \quad (1)$$

In the regression module of the Statgraphics Centurion XV®, new values of a and c and their P-values were obtained from the linear regression between the LM estimated values (obtained in the first calibration) and BT observed values.

The AL profile obtained with 0^{DC} was recalibrated with the corrected BT equation, creating a corrected AL animal profile. Following this, an RF animal profile was created to verify the predictive capacity of the system for BW and BT in this group. The model parameter values for the RF animal profile were copied from the recalibrated AL profile after the correction of the BT equation.

The BTc2 step: to predict BT from the RF group, the LMi value of the RF animal profile was manually adjusted, as described below. The LMi for the RF animal group (LMi_{RF}) was obtained directly by inserting the mean observed BWi for the RF group animals (BWi_{obsRF}) in the INRAPORC® animal profile window. The system decomposes initial BW values into LMi and initial protein mass (PMi) using the allometric equation described by van Milgen (2008), after re-analyzing data from Quiniou and Noblet (1995) (equation 2):

$$BW\ (kg) = \left(\frac{5.969PM^{0.944} + 0.854LM^{0.944}}{0.890}\right)^{0.986} \quad (2)$$

The LMi value of the RF animal profile was adjusted (LMi_{adjRF}) by multiplying LMi_{RF} by the ratio of the two LMi values from the AL animal profile: calculated LMi and estimated LMi (Equation 3). Both values depend on initial BW of the AL animal profile after system recalibration ($BWi_{recalbtAL}$).

$$LMi_{adjRF} = LMi_{Rf} * (LMi_{calcAL}/LMi_{estmAL}) \quad (3)$$

The system automatically decomposes $BWi_{recalbtAL}$ and estimates the LMi value of the AL animal profile (LMi_{estmAL}). The calculated LMi (LMi_{calcAL}) also uses the value of $BWi_{recalbtAL}$ but is obtained based on the mean performance of group AL using the equation describing the linear relationship between INRAPORC®-simulated LM (LM_{simAL}) and observed BW (BW_{obsAL}) from group AL (equation 4).

$$LM_{simAL} = e * (BW_{obsAL}) + d \quad (4)$$

Thus, the value of LMi_{calcAL} to be used in equation 3 was obtained by inputting the value of $BWi_{recalbtAL}$ in the BW_{obsAL} field of equation 4.

The reliability of equation 4 is due to the use of the actual BW value of the AL group, and not the value estimated by the system. This removes errors of AL group BW estimation that exist between equations comprised in the system. This relationship allowed a reliable linear adjustment of LM for genotype used in this study and percentage adjustment of LMi values of RF animal profiles. This adjustment is important and can be applied in situations where only the mean of the BWi values of the RF animal group are known.

The linear model between observed mean BW data (from the AL animal group of Pierozan (2014) experiment) and estimated LM data (from INRAPORC® estimates for AL animal profiles after INRAPORC® recalibration) was analyzed using the Statgrafics Centurium XV regression module. Values of d and e and their P-values were obtained (equation 4). This relationship allowed us to adjust the value of the initial LM of the animal profile subjected to restricted feed management (equation 3). After the LMi_{adjRF} value was obtained using equation 3, the BTc02 step and Corrected (1^{DC}) calibration procedure ended.

Other calibration procedures were performed in the advanced system calibration mode, which considered observed BT values and different combinations between actual, default, and estimated MP values, which were input in the INRAPORC® ACM, generating different calibration procedures (Table 3). Values of $LMiadj_{RF}$ were adjusted according to BWi values of AL animal profiles, obtained after the system recalibration, to predict the BT values for RF group animals.

These MP values were as follows: 19.50 MJ of net energy.day^{-1} (MJ NE.day^{-1}) for feed intake at 50 kg BW (FI50), 37.16 MJ NE.day^{-1} for feed intake at 100 kg BW (FI100), and 74.68 kg BWi. In addition, 1.00 was the default value for the MAINT. The FI50 value was obtained from feed intake data from the farm prior to the start of the experiment. The Statgraphics Centurion XV® outlier identification module was used to check if the FI100 actual value would be an outlier, applying Grubb's test to the dataset of mean diary feed intake. In addition to this test, the percentage of the actual FI100 value and values calibrated by the system were verified.

The calibration procedures (Table 3) were ordered by the calibration mode used, and the number of MP in each, with actual or default information input in ACM. It was also verified whether calibration procedures presented any matrix solution error, and those with this characteristic were discarded from the study. We did not develop any "discard data" standards other than this error message reported by the system.

All calibration procedures used the same CFI, BW, and BT database to calibrate the AL animal profile. To understand the relationship between estimated, actual, and default MP values from different calibrated animal profiles, a Pearson's correlation test between these values and their P-values was performed. This analysis was also useful to assess whether any BT or BW prediction error could be associated with the relationship between MP.

To obtain BW and BT predictions, we used RF animal profiles whose characteristics were calibrated based on data from the AL group, adjusted LMi_{adjRF} values, actual values of mean BWi, and feed allowance plan for the RF group.

Prediction error analyses of BW and BT were carried out on observed data and predicted data by INRAPORC® for the RF animal group to quantify values of systematic underestimation or overestimation. The model ($y = b_1 x + b_0$) was used to obtain a predictive calibration curve (H_0: $b_0 = 0$ and $b_1 = 1$), with the predicted (x) and observed (y) values. The parameters used in the analysis included: intercept value (b_0) and its statistical significance (b_0 P-value) and linear regression coefficient (b_1) and its statistical significance (b_1 P-value), $\alpha = 0.05$. These parameter values were obtained from the Statgraphics Centurion XV® calibration module hypothesis test. In this module, we were also able to obtain the standardized skewness value (which can determine whether samples or deviations of prediction come from a normal distribution), the coefficient of determination (R^2) value of the calibration curve, and the P-value for linearity of relationship between observed and predicted BT and BW data.

An error-decomposition method was also used to understand which systematic effects were influencing the prediction errors of INRAPORC®. The prediction error decomposition or the mean squared deviation (MSD) was obtained according to the method of Gauch et al. (2003), by adding up their components, including the mean square of the systematic errors of fixed effect (square bias, SB), mean square of the rate of systematic errors (non-unit slope, NU), and the error of correlation between the observed and estimated data (lack of correlation, LC). The standard deviation of the estimate (σ) was calculated as the square root of MSD.

Differences in performance between animal groups were verified using a t test for pairs of means. Equation 5 was used to verify BW and BT sampling sufficiency (Ƞ) of AL and RF groups (Fontelles et al., 2010):

$$Ƞ = ((Z_{(\alpha/2)} * \sigma)/(EL * \bar{x}))^2 \quad (5)$$

in which $Z_{(\alpha/2)}$ reflects the distribution value, Z, tabulated for $\alpha = 0.05$ (two-tailed); σ indicates the population standard deviation of the studied variable; EL represents the error limit or relative error (EL = 0.05, in this study); and $\bar{x}$ represents the sample mean.

To assess the correlations between MP values obtained in the different calibration procedures, coefficients of variation (CV%) and sample sufficiency were verified. We calculated correlations between SB of BW data from the RF group (SB_{BWRF}) and Bwi_{AL} and between SB of BT data from the RF group (SB_{BTRF}) and LMi_{adjRF}. The Ƞ value and CV% of these data sets were calculated. Values of SB were square root transformed, as they were quadratic values.

Calibration procedures 1^{DC}, 3, and 6 were used to verify if the analyzed diet values obtained *in silico* could interfere with the BT and BW prediction errors. These calibration procedures were chosen for this verification due to their characteristics: standard calibration (1^{DCa}), using ACM and observed BT data (3^a), and actual FI50 value (6^a). A paired t test was carried out on nutrient information calculated from the diet, based on INRAPORC® database and laboratory analyses.

3. Results

In the BTcor procedure, we initially corrected the coefficients a and c of the BT equation (Equation 1), which expresses the linear relationship between LM and BT based on the INRAPORC® simulated LM data, and the observed BT of the AL group of animals. Based on this finding, we obtained equation 6 (R^2 = 0.985) (P<0.01):

$$BT = 0.42 * LM + 5.27 \quad (6)$$

Equation 6 corresponds to the corrected calibration procedure (1^{DC}) presented in Table 3. Each calibration procedure presented different BT equations (Table 4). Following the BTcor procedure, the LMi value of the RF animal profile (LMi_{RF}) was manually adjusted. Two equations for LMi of the RF group were proposed for this purpose. The first, equation 7, was obtained by adjusting coefficients d and e of equation 4 to express the linear relationship between the observed BW (BW_{obsAL}) and the INRAPORC® simulated LM (LM_{simAL}) for the AL group (R^2 = 0.997) (P<0.01):

$$LM_{simAL} = 0.43 * BW_{obsAL} - 17.02 \quad (7)$$

Equation 7 corresponds to the corrected calibration procedure (1^{DC}) shown in Table 3. Each calibration procedure yielded different LM equations (Table 4). The second equation adjusted the LMi value of the RF animal profile (LMi_{RF}) (17.2 kg), estimated using the observed BWi (BWi_{obsRF}) for the RF group (78.5 kg) based on equation 2. The adjustment of the LMiRF value followed Equation 3, in which the LMi_{calcAL} value (14.78 kg) was obtained using the $BWi_{recalbtAL}$ (73.9 kg) in equation 7, and the LMi_{estmAL} value (15.83 kg) was obtained after system recalibration in the LMi field for the AL animal profile. The LMi_{adjRF} value was 16.06 kg.

Input MP Values, which can be estimated by INRAPORC®, force the system to have a different integrated matrix solution, interfering in the estimate values of other MP (Table 5). Among the different calibration procedures tested, only seven presented an integrated solution of results (Table 3). Other combinations of MP values generated calibrations with the following error messages: “Singular Hessian matrix” and “Invalid floating-point operation”. Thus, they were not included in the subsequent analyses. All calibration procedures that used the FI100 actual value (37.5 MJ $NE.day^{-1}$) presented this error. However, in the calibration procedures that were analyzed, the values were smaller and ranged from

Table 4 - Equations of backfat thickness prediction correction for each calibration procedure for animal groups under *ad libitum* feed management

Calibration procedure	Backfat thickness prediction correction equations	
	BT Equation (eq. 6)**	LM Equation (eq.7)**
1^{DC}	5.27 + 0.42 * LM	−17.02 + 0.43 * BW
2	6.21 + 0.39 * LM	−20.55 + 0.46 * BW
3	5.61 + 0.41 * LM	−18.10 + 0.44 * BW
4	6.31 + 0.39 * LM	−20.95 + 0.46 * BW
5	6.18 + 0.39 * LM	−20.43 + 0.46 * BW
6	6.14 + 0.40 * LM	−20.19 + 0.46 * BW
7	6.15 + 0.40 * LM	−20.22 + 0.46 * BW

[DC] Calibration procedure that used the default system calibration mode.
** All coefficient values (b_1 and b_0) were significant (P<0.01).

32.72 to 34.19 MJ NE.day^{-1} (Table 5). The actual FI100 value was not an outlier based on Grubb's test value (1.69 and P = 0.80) for the dataset of mean diary feed intake. The percentage of the actual FI100 value for the values calibrated by the system ranged from 108 to 113%.

The MP values obtained from seven different calibration procedures are shown in Table 5. To correlate MP values, a sample sufficiency Ƞ < 1.1 and CV% < 2.7% was obtained for FI100, MeanPD, MAINT, and BWi, and Ƞ = 6.5 and CV% = 6.5% was obtained for precocity. The seven observations were not sufficient for FI50 values, Ƞ, and the CV% was higher: Ƞ = 17.9 and CV% = 10.8%.

A strong positive correlation (r>0.98) was observed among FI50, FI100, and MeanPD (P<0.01) (Table 6). These three parameters presented a strong negative correlation (r<−0.87) with BWi; meanwhile, BWi had a strong positive correlation with MAINT value (r = 0.75) (P = 0.05). That is, higher BWi values yielded higher MAINT values, thus reducing the MeanPD value. The estimated FI50 values were greater than the actual values (Table 5) and showed a strong and positive correlation with MeanPD (r = 0.986) (Table 6). The MeanPD values were lower for calibration procedures that used FI50 actual data (< 135.9 g.day^{-1}) than calibration procedures that did not use FI50 actual data (> 140.9 g.day^{-1}), for example, the NONE calibration procedure (143.0 g.day^{-1}), but the BWi values showed the opposite behavior (Table 5).

As a result, at the end of the trial period, predicted BW values under the different calibration procedures were similar, while the predicted condition of the animal at maturity did not vary much between the different calibration procedures (CV% = 0.7% for final BW at 210 days of age). The CV% was 1.7%

Table 5 - Coefficients of determination (R^2) for estimates of model parameters and dependent variables after different system calibration procedures for animal profiles under *ad libitum* feed management

Calibration procedures characterized by actual or default model parameter values	Calibration curve-dependent variable		Animal profile model parameters after calibration					
	Variable	R^2	FI50 (MJ NE/d)	FI100	MeanPD (g/d)	Precocity (1/d)	MAINT –	BWi (kg)
DEFAULT (1[DC])	CFI	0.9995	23.84	34.02	140.9	0.0138	1.000[d]	73.90
	BW	0.9991						
	BT	–						
NONE (2)	CFI	0.9996	24.29	34.19	143.0	0.0159	0.945	71.80
	BW	0.9979						
	BT	0.9846						
MAINT (3)	CFI	0.9995	24.41	34.17	143.5	0.0137	1.000[d]	73.10
	BW	0.9988						
	BT	0.9858						
FI50 (4)	CFI	0.9969	19.50[a]	32.77	134.4	0.0144	1.003	75.70
	BW	0.9983						
	BT	0.9757						
FI50/BWi (5)	CFI	0.9965	19.50[a]	32.72	135.3	0.0163	0.985	74.70[a]
	BW	0.9988						
	BT	0.9750						
MAINT/FI50 (6)	CFI	0.9969	19.50[a]	32.74	135.2	0.0148	1.000[d]	75.40
	BW	0.9984						
	BT	0.9759						
MAINT/FI50/BWi (7)	CFI	0.9968	19.50[a]	32.82	135.9	0.0158	1.000[d]	74.70[a]
	BW	0.9988						
	BT	0.9756						

CFI - cumulated feed intake; BW - body weight; BT - backfat thickness; Default or 1[DC] - calibration procedure in the system default calibration mode, which does not consider backfat thickness as a calibration curve dependent variable; MAINT - maintenance adjustment coefficient, with its default value set at 1.00; FI50 - feed intake at 50 kg BW expressed in MJ NE/d; FI100 - feed intake at 100 kg BW expressed in MJ NE/d; BWi - initial body weight; NONE - parameter values estimated by the system; MeanPD - mean potential daily deposition of protein in g/d; precocity - ($B_{Gompertz}$) growth curve shape coefficient for Gompertz function that characterizes the animal growth profile.
[a] Actual value.
[d] Model parameter default values provided for system calibration.

for BWi at the beginning of the trial at 128 days of age, which indicated greater initial variation in animal profiles. Actual data from some MP influenced prediction errors in BW and BT of RF animals. Calibration procedures 4-7, which were based on actual FI50 data, produced an average BW σ estimate 21% lower than other procedures.

The relationships between the data predicted by INRAPORC® and those observed for BT and BW were significant in a linear model (P<0.001) with a value of R^2>0.986 for all analyzed calibration procedures. The normality test using a standardized skewness value for prediction deviations showed that all BT and BW data were within the test acceptance range of −2 to +2; the observed range was from −0.915 to 1.222.

The energy balance between LD and PD provided lower σ values for BW and higher σ values for BT in calibration procedures that used the actual FI50 value (Tables 7 and 8). The highest BW σ value was

Table 6 - In lower diagonal, correlations among model parameters after different system calibration procedures for animal profiles under *ad libitum* feed management, and in the upper diagonal, correlation P-values

Parameter	Correlations among animal profile model parameters					
	FI50	FI100	MeanPD	Precocity	MAINT	BWi
FI50	1.000	0.000	0.000	0.346	0.360	0.010
FI100	0.999	1.000	0.000	0.363	0.346	0.009
MeanPD	0.986	0.986	1.000	0.459	0.313	0.004
Precocity	−0.398	−0.394	−0.332	1.000	0.193	0.909
MAINT	−0.424	−0.423	−0.449	−0.565	1.000	0.050
BWi	−0.880	−0.883	−0.917	−0.068	0.746	1.000

MAINT - maintenance adjustment coefficient; FI50 - feed intake at 50 kg BW expressed in MJ NE/d; FI100 - feed intake at 100 kg BW expressed in MJ NE/d; BWi - initial body weight; MeanPD - mean potential daily deposition of protein in g/d; precocity - ($B_{Gompertz}$) growth curve shape coefficient for Gompertz function that characterizes animal profile.

Table 7 - Prediction error of INRAPORC® for body weight of the animal group under restricted feed management, based on prediction calibration curve (b_0 = 0 and b_1 = 1) and decomposition of mean square deviation (MSD) for each calibration procedure

Calibration procedure	Parameter of analysis							
	Body weight							
	b_0 (kg)	b_0 P-value	b_1	b_1 P-value	SB	NU	LC	σ (kg)
Original (0[DC])	7.28	0.0040**	0.90	0.0001**	20.79	5.46	1.67	5.28
Orig.(BTc1[DC])	7.24	0.0042**	0.90	0.0001**	20.68	5.42	1.67	5.27
Corrected (1[DC])	7.25	0.0043**	0.90	0.0001**	20.89	5.39	1.69	5.29
Corrected (1[DC])[a]	7.19	0.0045**	0.90	0.0001**	20.89	5.39	1.69	5.29
2	8.32	0.0049**	0.88	0.0001**	38.85	8.41	2.36	7.04
3	8.16	0.0018**	0.89	0.0000**	25.72	6.94	1.67	5.86
3[a]	8.24	0.0022**	0.89	0.0000**	28.68	7.34	1.80	6.15
4	4.09	0.1059	0.94	0.0066**	12.41	2.13	2.10	4.08
5	4.68	0.0982	0.92	0.0041**	20.33	3.13	2.64	5.11
6	4.48	0.0875	0.93	0.0043**	18.90	2.92	2.57	4.94
6[a]	4.54	0.1033	0.93	0.0046**	14.99	2.57	2.20	4.44
7	4.55	0.1070	0.92	0.0048**	19.61	2.98	2.64	5.02

Original - original calibration procedure with original system equations and values for backfat thickness (BT) equation; Orig.BTc1 - calibration procedure with BT equation coefficients corrected, but initial lipid mass value of restricted (RF) animal profile was not changed manually; Corrected - original calibration procedure with equations and corrected values of lipid partition, after BTcor procedure; b_0 - intercept value; b_0 (P-value) - statistical significance percentage of intercept, null intercept probability; b_1 - linear regression coefficient value; b_1 (P-value) - statistical significance percentage of linear regression coefficient, unit slope probability; σ - standard deviation of results between the observed and estimated mean data representing the precision of system estimates; SB - square bias, representing the mean square of systematic fixed effect errors, NU - non-unit slope, representing mean square of systematic error rates; LC - lack of correlation between observed and predicted mean data.
[DC] Calibration procedures using the system default calibration mode.
[a] Nutrient content of diet as analyzed.
** α = 1% level of statistical significance.

obtained using calibration procedure NONE or 2 (σ = 7.04 kg; Table 7), whereas the lowest σ value was obtained using calibration procedure 4 (σ = 4.08 kg; Table 7). Because the system was calibrated based on AL group performance data, the NONE calibration procedure presented the best fit for the AL group data (R^2 = 0.996), compared with calibration procedure 4 (R^2 = 0.993; Table 5). Calibration procedure 4 led to the closest simulated performance to the actual RF group performance, reflecting the difference in AL and RF animals. These groups presented coefficients of variation for BWi of 6.20 and 5.03%, with a sample sufficiency of 5.91 and 3.90 animals per group, respectively (equation 5), with six animals housed in each group. The RF group showed a significant difference to the AL group (RF – AL) in average mean performance during the test period for BW (−2.336 kg; P = 0.03) and BWi (3.842 kg; P = 0.01).

For BW data, the calibration procedures using FI50 actual value yielded an SB value of 38% and an NU value of 60%, lower than those that did not use this information (Table 7). The effect of the FI50 value on NU results from its strong positive correlation with MeanPD (Table 6), which also influenced the calibrated animal profile, due to the moderate correlation of FI50 with precocity (r = −0.40). The effect of FI50 on SB results from its strong and negative correlation with BWi (r = −0.880).

Comparison between BT predictions obtained after the original calibration procedure (0^{DC}), not subjected to the BTcor procedure, and those from the corrected calibration procedure (1^{DC}), showed a significant reduction in fixed effect systematic error (P<0.01), but still overestimated BT. This was represented by an intercept change (b_0) from −4.85 to −1.94 mm, a 45% reduction in the SB value from 10.34 to 5.73 (Table 8), and a change in the BT standard estimate deviation value (σ) from 3.25 to 2.42 mm. These reductions are associated with initial animal state, as corrections of the RF animal profile LMi value.

The BTcor procedure also reduced the systematic error rate, represented by parameters b_1 and the NU. Due to the original (0^{DC}) and corrected (1^{DC}) calibration procedures (Table 8), b_1 values decreased from 1.09 to 0.97 (from P = 0.04 to P = 0.48), and NU decreased by 83% from 0.06 to 0.01. The reductions

Table 8 - Prediction error of INRAPORC® for backfat thickness of the animal group under restricted feed management, based on the prediction calibration curve (b_0 = 0 and b_1 = 1) and decomposition of the mean square deviation (MSD) for each calibration procedure analyzed

Calibration procedure	Backfat thickness (BT)							
	b_0 (mm)	b_0 P-value	b_1	b_1 P-value	SB	NU	LC	σ (mm)
Original (0^{DC})	−4.85	0.0000**	1.09	0.0425*	10.34	0.06	0.13	3.25
Orig.(BTc1^{DC})	−2.40	0.0078**	0.97	0.4742	8.71	0.01	0.13	2.98
Corrected (1^{DC})	−1.94	0.0092**	0.97	0.4754	5.73	0.01	0.13	2.42
Corrected (1^{DC})[a]	−1.88	0.0097**	0.97	0.4141	5.73	0.01	0.13	2.42
2	−1.80	0.0140*	0.99	0.7884	3.85	0.00	0.13	2.00
3	−2.11	0.0060**	1.00	0.9157	4.74	0.00	0.13	2.21
3[a]	−2.04	0.0072**	1.00	0.9157	4.63	0.00	0.13	2.18
4	−2.72	0.0015**	1.03	0.3847	4.59	0.01	0.13	2.17
5	−2.30	0.0040**	1.01	0.7905	4.55	0.00	0.13	2.16
6	−2.49	0.0025**	1.01	0.6611	4.61	0.00	0.13	2.18
6[a]	−2.41	0.0029**	1.01	0.7321	4.84	0.00	0.13	2.23
7	−2.45	0.0028**	1.02	0.5799	4.36	0.00	0.13	2.12

Original - original calibration procedure with original system equations and values for BT equation; Orig.BTc1 - calibration procedure with corrected BT equation coefficients, but initial lipid mass value of the restricted (RF) animal profile was not changed manually; corrected - original calibration procedure with equations and corrected values of lipid partition, after BTcor procedure; b_0 - intercept value; b_0 (P-value) - statistical significance percentage of intercept, null intercept probability; b_1 - linear regression coefficient value; b_1 (P-value) - statistical significance percentage of linear regression coefficient, unit slope probability; σ - standard deviation of results between the observed and estimated mean data representing the precision of system estimates; SB - square bias, representing the mean square of systematic fixed effect errors, NU - non-unit slope, representing mean square of systematic error rates; LC - lack of correlation between observed and predicted mean data.
[DC] Calibration procedures using the system default calibration mode.
[a] Nutrient content of diet as analyzed.
* α = 5% level of statistical significance.
** α = 1% level of statistical significance.

in rate errors are linked to mechanical corrections, such as the BT equation coefficients. The BTcor procedure had no effect on BW predictions (Table 7).

For BT data, the BTc1 step reduced 100% of the systematic rate error (NU) and 35% of the fixed effect error (SB) in results from the original (0^{DC}) calibration procedure to the BTc1 calibration procedure (Orig.BTc1) (Table 8). In the BTc2 step, the fixed effect error of BT predictions was reduced. In results of the Orig.BTc1 calibration procedure and the 1^{DC} calibration procedure: b0 decreased from −2.40 to −1.94 mm, and SB decreased from 8.71 to 5.73 (Table 8). Thus, from the BTc1 to the BTc2 step, the fixed effect error decreased by 65%.

The SB_{BWRF} value accounted for at least 75% of the MSD for BW, and SB_{BTRF} accounted for 97% of BT. The SB_{BWRF} was highly correlated with BWi_{AL} (r = −0.96), and SB_{BTRF} was also highly correlated with LMi_{adjRF} (r = 0.98). The Ƞ values for SB_{BWRF}, SB_{BTRF}, BWi_{AL}, and LMi_{adjRF} were 6.4, 4.7, 0.4, and 2.2, respectively, and CV% values were 6.4, 5.6, 1.7, and 3.8%, respectively. Initial LM values had a strong influence on the predicted BT, as did the BWi value for the BW predictions. Deviations from the animal profile initial values are the main cause of the systematic fixed effect errors of INRAPORC®.

The use of calculated and analyzed nutrient compositions had little influence on the BT and BW prediction errors. All b_1 values for BT and BW remained the same. For b_0 values, the difference was from 0.06 to 0.08 kg for BW and from −0.06 to −0.08 mm for BT (Tables 7 and 8). The difference in energy density values between diets in dry matter was 0.1 MJ $NE.kg^{-1}$. A paired two-tailed t test showed no differences between the calculated and analyzed nutrient compositions (P = 0.80). The actual FI50 value used in ACM promoted greater differences in prediction errors for BW (3.7 kg) and BT (0.38 mm).

Calibrations with analyzed diet values made the MeanPD values higher than those from calibrations with calculated nutrient values (from 0.05 to 0.13 $g.day^{-1}$, depending on the calibration procedure). Sometimes the prediction errors were higher for BT and sometimes for BW (Tables 7 and 8). The actual value of FI50 used in ACM caused a difference of 8.30 $g.day^{-1}$ in the MeanPD calibrated value.

The efficiency of FI50 information in reducing errors mainly resulted from the fact that BW predictions already had significant rate and fixed effect errors (P<0.01; Table 7) in the default system calibration. When calibration procedure 4 was used (which only reported the actual FI50value), the significance of b_1 and b_0 became P<0.01 and 0.1059, respectively. In line with this, the standard deviation of estimates between the observed and predicted data obtained for BW based on the default system calibration for RF animals (representing the precision of the system), was higher (7.04 kg) than that obtained with the procedures using the actual FI50 (<5.11 kg).

4. Discussion

Correction in the BT equation (equation 6) is performed as a function of lipid tissue distribution in the animal's body, which has different patterns depending on the animal's genetics, age, and sex (Kloareg et al., 2006). Because there may be systematic errors in BT and LM predictions, the system must be recalibrated after correcting the BT equation coefficients. The corrected equation, when integrated into the mathematical optimization process of the model, will affect both the predicted BT value and the dynamics of the lipid deposition (LD) simulation by INRAPORC®. Therefore, the corrected equation starts to influence the energy partition simulation between LD and PD, because the original equation could not be adjusted to the genotype of Brazilian pigs (Warpechowski et al., 2014). With the equation adjustment and system calibration, mechanistic and system dynamics changes occur, changing prediction values of physiological and tissue processes (Lovatto and Sauvant, 2001) to influence the values of systematic rate errors.

The animal profile initial state in INRAPORC® was adjusted because the system equations that break down BWi into PMi and LMi contribute to systematic fixed effect errors, just as in equation 2 (proposed by Quiniou and Noblet (1995) and re-analyzed by van Milgen et al. (2008)). In the original study, there was an equation for each genotype, sex, and performance of pigs weighing 15-110 kg. However, the equations were not relaxed within the INRAPORC® system according to these sources of variation. By manually adjusting the BWi value as a function of equation 2, we also adjusted the LMi value. Manual adjustment of values in the initial animal profile was recommended by INRAPORC® authors to reduce errors (van Milgen et al., 2015).

Another source of overestimation of BT prediction values of INRAPORC® is LD overestimation owing to the underestimation of the system of the body reserves used for maintenance (van Milgen et al., 2008), even after BTcor procedure, which may be responsible for rate errors. For BT results from the RF animal group, the default system calibration presented the highest σ, as it was based only on CFI and BW data and did not consider observed BT data from the AL group for calibration. Observed data (such as BT) can be used as inputs for INRAPORC® calibrations to make estimates as close as possible to observations (van Milgen et al., 2008).

The system is calibrated by iterations, and calculation is halted when it reaches the smallest error values of the estimation of dependent variables in the calibration curve. Thus, the system adjusts the values of all MP, which have different characteristics and describes the dynamics of animal growth and feed intake (van Milgen et al., 2008), yielding a calibrated animal profile for each calibration procedure performed.

In this study, the correlations obtained between MP values (Table 6), which originated from different calibration procedures (Table 3), had characteristics relating MP data from animal profiles that used the same data observed for CFI, BT, and BW in the AL animal group in their calibrations. In previous studies, correlations were assessed between MP values obtained from calibrated animal profiles, unique for each group or population of animals (Brossard et al., 2006 and Vautier et al., 2013).

By maintaining the same database for the calibration curve dependent variables, each MP value used in ACM generates a different matrix solution for the system calibration; therefore, the system returned different values for the other MP in each calibration procedure.

Some of these calibrations returned error values; in addition, it was observed that the animal performance did not follow biological standards consistent with the pig development stage observed for the AL group, presenting biological incoherence. Biological coherence must agree with major biological concepts (Lovatto, 2003).

The FI100 actual value caused these calibration errors, and the system was unable to integrate it with the independent variable actual values of the AL group. Its NE level was high enough to cause calibration errors, but it was not an outlier; its values estimated by the system were lower. The FI50 actual value showed calibrations with matrix solutions, but it was less than those estimated by the system. The estimated energetic amplitude between FI50 and FI100 was a maximum of 10.18 MJ NE.day^{-1} and actual amplitude was 14.00 (137.5%). This greatly influenced the animal profiles by integrating only the FI50 actual value in the system calibration, mainly based on the use of NE and PD potential and initial state BWi (Table 5).

Among the different matrix solutions of the system, some characteristics in the correlations can be obtained. Owing to the fact that INRAPORC® preserves the same final body composition of the animal at maturity (van Milgen et al., 2008), we observed the following correlations obtained between MP. In this study, the animal profiles from the AL group with a lower feed intake and, consequently, low NE intake at 50 and 100 kg BW, had a lower MeanPD or lower growth magnitude. To maintain the body state at maturity, the system returned higher estimates of BWi for these animal profiles. In a study by Vautier et al. (2013), FI50, FI100, and MeanPD also showed a positive correlation with one another, but only FI50 showed a negative correlation with BWi.

The high correlation between MeanPD and feed intake at 50 kg BW (FI50) (r = 0.986) agrees with a report by Brossard et al. (2006) (r = 0.66), in which the voluntary FI50 is required by PD, reflecting in animal growth potential. The relationship between BWi and MAINT (r = 0.75) follows the same logic, in which the higher the NE required for maintenance (NEmaint), the lower the net energy available for LD and PD, and the higher the BWi estimate required for an animal to reach the same body condition at maturity (Brossard et al., 2006). In contrast, the higher BW, the greater demand for NEmaint (van Milgen et al., 2008), as the energy consumed during growth in the trial is the same for all animal profiles; if the demand for NEmaint increases, the BWi will also have higher estimates.

MeanPD has a strong influence on the growth dynamics of an animal and on rate errors, because these MP determine the NE partitioned between PD and LD (van Milgen et al., 2008). The equilibrium between LD and PD also depends on the composition of LMi and PMi in BWi, because in the system, the equation that describes the growth potential of pigs from PD depends on MeanPD and PMi values (van Milgen et al., 2015). Based on this result, information on the actual feed intake at 50 kg BW (FI50) influenced the fixed effect and rate errors owing to their strong correlations with the MP, MeanPD, and BWi. The MeanPD is correlated with rate errors, as it modulates the magnitude and rate of growth dynamics of animals, and BWi is correlated with fixed errors, as it modulates the initial state of the animal and is decomposed by the system as LMi and PMi (van Milgen et al., 2008; Vautier et al., 2013; van Milgen et al., 2015).

Just using actual BT data in the AL animal group improved accuracy in the predicted BT values for the RF profile. The use of actual MP data in ACM can result in a calibrated animal profile of greater precision in the predictions obtained for other animal groups for which nutritional adjustment is to be performed; in this study, that was the RF animal group. As there were variations in MP values between distinct groups or populations (Vautier et al., 2013), the actual MP values manually input in the system can have this effect on the predictions obtained.

The difference in energy density between calculated and analyzed nutrient compositions interacts with PD, as this is limited by NE availability, and thus MeanPD calibrated value may be influenced. The MeanPD is directly linked to PMi and PD energy partitioning (van Milgen et al., 2008). The MeanPD values are influenced by the actual FI50 value that modulates feed intake, and thus, the dynamics of energy supply in the model (Brossard et al., 2006) and also changes initial values and LD and PD dynamics.

5. Conclusions

The backfat thickness prediction correcting procedure efficiently reduced backfat thickness prediction errors, but the predicted backfat thickness values were still overestimated. Actual backfat thickness values in advanced system calibration mode improve the accuracy of backfat thickness predictions. Fixed effect systematic errors were linked to initial lipid mass and protein mass values. Adjustment of initial body weight values in the animal profile window improved initial lipid mass and lipid mass estimations. Model parameter estimates were strongly correlated, and the input of their actual values in the INRAPORC® advanced calibration mode influenced other model parameters values and improved the accuracy of body weight prediction. The system presented calibration procedures with an error message in its matrix solutions. These calibrations should not be used. The system user should know that it is possible to obtain different calibrations and results for the same database. When there is limited information on a population for which a nutritional strategy will be developed in INRAPORC®, it is advisable to use the default calibration mode.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: S.F. Magagnin, L. Hauptli and M.B. Warpechowski. Data curation: S.F. Magagnin, L. Hauptli and M.B. Warpechowski. Formal analysis: S.F. Magagnin, L. Hauptli and M.B. Warpechowski. Funding acquisition: M.B. Warpechowski. Investigation: S.F. Magagnin, L. Hauptli and M.B. Warpechowski. Methodology: S.F. Magagnin, L. Hauptli and M.B. Warpechowski. Project administration: M.B. Warpechowski. Resources: S.F. Magagnin, L. Hauptli and M.B. Warpechowski. Software: S.F. Magagnin and M.B. Warpechowski. Supervision: L. Hauptli and M.B. Warpechowski. Validation: S.F. Magagnin, L. Hauptli and M.B. Warpechowski. Visualization: L. Hauptli and M.B. Warpechowski. Writing-original draft: S.F. Magagnin. Writing-review & editing: S.F. Magagnin, L. Hauptli and M.B. Warpechowski.

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References

Brossard, L.; van Milgen, J.; Lannuzel, P. Y.; Bertinotti, R. and Rivest, J. 2006. Analyse des relations entre croinssance et ingetion à partir de cinétiques individualles: implications dans la définition de profils animaux pour la modélisation. Journées Recherche Porcine 38:217-224.

Fontelles, M. J.; Simões, M. G.; Almeida, J. C. and Fontelles, R. G. S. 2010. Metodologia da pesquisa: diretrizes para o cálculo do tamanho da amostra. Revista Paraense de Medicina 24:57-64.

Gauch, H. G.; Hwang, J. T. G. and Fick, G. W. 2003. Model evaluation by comparison of model-based predictions and measured values. Agronomy Journal 95:1442-1446. https://doi.org/10.2134/agronj2003.1442

Kloareg, M.; Noblet, J. and Van Milgen, J. 2006. Estimation of whole body lipid mass in finishing pigs. Animal Science 82:241-251. https://doi.org/10.1079/ASC200529

Lovatto, P. A. and Sauvant, D. 2001. Modelagem aplicada aos processos digestivos e metabólicos do suíno. Ciência Rural 31:633-670. https://doi.org/10.1590/S0103-84782001000400017

Lovatto, P. A. 2003. Princípios de modelagem e sua aplicação no estudo de cadeias de produção agrícola. p.1-22. In: Anais da 40ª Reunião Anual da Sociedade Brasileira de Zootecnia, Santa Maria.

Pierozan, E. A. 2014. Avaliação e modelagem do desempenho, digestibilidade e produção de efluente na terminação de suínos pesados. Dissertação (M.Sc.). Universidade Federal do Paraná, Curitiba.

Quiniou, N. and Noblet, J. 1995. Prediction of tissular body composition from protein and lipid deposition in growing pigs. Journal of Animal Science 73:1567-1575. https://doi.org/10.2527/1995.7361567x

van Milgen, J.; Valancogne, A.; Dubois, S.; Dourmad, J. Y.; Sève, B. and Noblet, J. 2008. InraPorc: A model and decision support tool for the nutrition of growing pigs. Animal Feed Science and Technology 143:387-405. https://doi.org/10.1016/j.anifeedsci.2007.05.020

van Milgen, J.; Dourmad, J. Y.; Noblet, J.; Labussière, E.; Garcia-Launay, F.; Dubois, S.; Valancogne, A. and Brossard, L. 2015. InraPorc: Where do we come from and where do we want to go? p.22-37. In: Nutritional modelling for pigs and poultry. Sakomura, N. K.; Gous, R. M.; Kyriazakis, I. and Hauschild, L., eds. CAB International, Wallingford, UK.

Vautier, B.; Quiniou, N.; van Milgen, J. and Brossard, L. 2013. Accounting for variability among individual pigs in deterministic growth models. Animal 7:1265-1273. https://doi.org/10.1017/S1751731113000554

Warpechowski, M. B.; Brossard, L.; Hauptli, L.; Pierozan, E. A.; Quadros, J. A.; Muchalak, D. N.; Machado, M. F. and Scandolera, A. J. 2014. Evaluation du modèle nutritionnel InraPorc pour un système de finition de porcs lourds du sud du Brésil. Journées Recherche Porcine 46:133-134.