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ANIMAL PRODUCTION

Correction of INRAPORC® prediction errors for a commercial pig system

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ABSTRACT: *INRAPORC® is a mechanistic, dynamic, and deterministic model system that is used in commercial pig production. However, its use is limited as it requires performance information for animals under ad libitum (AL) feed management, which is not provided at all stages of production. Verification of the INRAPORC® calibrations were conducted in this investigation using data from a small group of animals fed with AL in a laboratory situation, to simulate the mean kinetics of a larger commercial population and generate the correction equations for the predicted body weight (BW), and backfat thickness (BT). Analyses were performed by comparing the predicted and observed data, and by submitting them to prediction calibration curve tests (b_0 = 0, and b_1 = 1). The obtained curves presented a systematic, fixed effect error (+2.37 mm) for BT. The predicted BW and BT values were corrected using the values of the systematic errors obtained. As a result, 100% of the BW averages observed were contained in the confidence intervals (CI) of the INRAPORC® predicted averages, without the need for corrections, and 78.5% of the actual BT averages were contained in the CI of the averages predicted by the system, after corrections. The INRAPORC® calibrations, based on a small population of animals in laboratory conditions could thus be utilized to make predictions for commercial pig production systems and for value correction procedures for the BW and BT of pig populations that have systematic errors in their prediction validations.*
Key words: *calibration validation, systematic error, predicted value correction procedure.*

Correção de erros de predição do INRAPORC® para um sistema comercial de suínos

RESUMO: *O INRAPORC® é um sistema de modelos mecanicista, dinâmico e determinista. Seu uso em sistemas comerciais de produção de suínos é restrito, pois necessita de informações de desempenho de animais sob manejo alimentar à vontade (AV), uma vez que este manejo não é utilizado em todas as fases de produção. Por isso é interessante verificar se a calibração do INRAPORC® baseada em um pequeno grupo de animais AV em situação laboratorial é capaz de simular a cinética média de uma população comercial maior e de subsidiar equações de correção de dados preditos de peso vivo (PV) e espessura de toucinho (ET). As análises foram realizadas comparando os dados preditos e observados sob o teste da curva de calibração da predição (b_0=0 e b_1=1), as curvas obtidas apresentaram erro sistemático de efeito fixo para a ET de +2,37mm. Os valores preditos de PV e ET foram corrigidos utilizando os valores dos erros sistemáticos obtidos. Como resultado, 100% das médias observadas de PV, estavam contidas nos intervalos de confiança (IC) das médias preditas pelo INRAPORC®, sem necessidade de correções e 78,5% das médias reais de ET estavam contidas nos IC das médias preditas pelo sistema, após as correções. A calibração do INRAPORC® baseada em uma pequena população de animais em situação laboratorial pode ser aplicada para predições de um sistema comercial de criação de suínos, bem como a aplicação do procedimento de correção dos dados preditos de PV e ET nas populações suínas que apresentem erros sistemáticos nas validações preditivas do sistema.*
Palavras-chave: *validação de calibração, erro sistemático, procedimento de correção de valores preditos.*

INTRODUCTION

INRAPORC® is a model system developed and distributed by the Institut National de La Recherche Agronomique (INRA) that utilizes the INRA-CIRAD-AFZ (Centre de Coopération Internationale en Recherche Agronomique pour le Développement - Association Française de Zootechnie) database and is an important tool used to help design nutritional strategies for pigs (VAN MILGEN et al., 2008). It is a mechanistic model that considers in its simulations, animal physiological processes and characteristics, making it flexible, as it can be used to assess animal performance in a variety of conditions (HAUSCHILD et al., 2012). It is thus dynamic and can provide nutritional requirements, and performance advice over time, and is deterministic, as it gives results for a median

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animal, without presenting the values of the population variations (LOVATTO & SAUVANT, 2001).

To use INRAPORC® and benefit from its full performance potential, it is necessary to calibrate it with the average data for a population of animals under *ad libitum* feed management (AL) (VAN MILGEN et al., 2008). However, in commercial farms, AL management is not practiced at all stages of production, so it is necessary to calibrate the system with data from a small group of animals in a laboratory situation and use this as a simulation of the larger commercial population. In this process, prediction errors can occur as a function of genetic, individual, and environmental variations between one population and another (POMAR et al., 2003). The population deviations for Brazilian conditions have not yet been verified for the INRAPORC® calibrations but are required to improve its use.

INRAPORC® makes predictions for performance data and nutritional needs based on an individual that is proposed to represent the medium of a population (VAN MILGEN et al, 2008); however, there will be animals in the population that have nutritional requirements above or below the simulated curve (KNAP, 2000). Due to variations among individuals in the population, there are differences between the medium kinetic population, and individuals (POMAR et al., 2003), and this error type can exist when comparing the averages predicted by INRAPORC® with actual population averages.

This study verified the INRAPORC® prediction errors for body weight (BW), and backfat thickness (BT), based on the data from a small group of animals under laboratory conditions, and determined if the system calibrations based on this group could be extrapolated to a commercial pig system. Furthermore, we determined if the calibration curve equations for the BW and BT prediction values could be used to correct possible deviations from the population averages that were predicted by the system.

MATERIALS AND METHODS

To calibrate INRAPORC®, the data for six barrows that were receiving *ad libitum* feed management (AL), with initial body weights (BWi) of 74.68 ± 5.07 kg, as reported previously by PIEROZAN (2014), were used. In parallel to this group, in the same experiment, data of another six barrows receiving restricted feed management (RE) of an average of 2.721 kg/day, with BWi of 78.53 ± 3.95 kg, were used. Both groups of pigs were descended from the commercial genetic line, AGROCERES PIC, and were managed under the same temporal and environmental conditions.

The calibration procedure used to predict the BW and BT of the RE group utilized the actual values of their dietary composition and amino acid profiles at zero percent wastage, food intake up to 50 kg in body weight (FI50), BT, BW, and cumulative feed intake from the AL animal groups. Data from the AL group was used to calibrate INRAPORC® and that from the RE group was used to evaluate the accuracy of the BT and BW predictions. The data pertaining to the observed BW and BT were collected weekly during the Pierozan (2014) experiment, and each animal had 13 observations, with 78 observations per group, and 156 observations in total. In this study, INRAPORC® version 1.6.5.7 was used.

The actual and predicted BW and BT data from the RE animal group were submitted to the prediction calibration curve test. The coefficients and statistical significance (αb_1, $b_1 = 1$, and αb_0; $b_0 = 0$) were determined using the Statgraphics Centurion 15® calibration module hypothesis test, which supplied the data for the correction equations of the BW and BT predictions.

Experiments by OLIVEIRA et al. (2015), provided data from two commercial pig populations (farms) slaughtered in two consecutive years (2009 and 2010). These populations consumed the same diet and belonged to the same gender (barrows), and genetic descent (AGROCERES PIC). Farm 01 (F01) in 2009 provided data for 76 barrows, and Farm 02 (F02) in 2010 provided data for 116 barrows. The slaughters were staggered so that they were close to the target slaughtering body weights of 100 kg (n = 22, and 28), 115 kg (n = 18, and 29), 130 kg (n = 18, and 31), and 145 kg (n = 18, and 28), from F01 and F02, respectively. There were thus four animal lots that were slaughtered per farm, totaling eight lots. Each pen housed groups of 10 to 11 animals, and all the animals in each pen were slaughtered at the same time. Each farm provided five actual population averages for body weight, and the animals were weighed at the start of the test (initial body weight - BWi), and at slaughter (final body weight), and four observations for backfat thickness (population averages) were collected at slaughter using a pachymeter at point P2. In the F01 animals, the average BWi was 85.022 ± 7.096 kg, and they consumed an average of 2.357 kg/day of feed and in F02 the average BWi was 77.827 ± 7.272 kg, and they consumed an average of 2.730 kg/day.

The production systems were evaluated using prediction errors from a previous calibration of INRAPORC® data from the PIEROZAN (2014) experiment in a commercial pig system, and from OLIVEIRA et al. (2015), providing 10 observations for BW, and eight for BT, considering F01, and F02 as a single farm. To consider them as the only herd, a *t*-test was performed for independent samples.

The actual BW and BT data were compared with those predicted by the calibration curve hypothesis test (b_0 = 0, and b_1 = 1) of the Statgraphics Centurion 15 calibration module, generating prediction calibration test curves. The *t*-test for the paired samples was used to verify the accuracy between the actual and predicted averages for the slaughtered lots. This facilitated verification of whether the INRAPORC® calibrations from a small group of animals in a laboratory situation could be extrapolated to a commercial pig population.

BW and BT data for each slaughter lot were analyzed in the distribution adjustment mode of the Statgraphics Centurion 15 using the Komolgorov-Smirnov method, verifying the population probability of each slaughtered lot presenting normal data distributions.

To verify the BW and BT sampling sufficiency (Ƞ) of F01 and F02, in a single herd, and of each lot of six animals for the AL and RE of the Pierozan (2014) experiment, equation 1 was used (FONTELLES et al., 2010):

$$Ƞ=((Z_{(\alpha/2)} \times \sigma)/(EL \times \bar{x}))^2((Z_{((1-\alpha)/2)} * \sigma)/(EL * \bar{x}))^2 \quad (1)$$

Where: $Z_{((1-\alpha)/2)}$ is the distribution value of Z tabulated for (α = 0.05; two-tailed); σ is the population standard deviation of the studied variable; EL is the error limit or relative error (in this study 5% was used); and $\bar{x}$, is the value of the sample mean.

After predicting the BW and BT averages with INRAPORC®, the corrected averages were calculated, based on the prediction calibration curves between the actual and predicted BW and BT data, from the PIEROZAN (2014) experiment. The actual averages of the BT and BW from F01 and F02 were contained in the confidence interval (CI) of the corrected averages, obtained from the actual population variations in each lot slaughtered at the target slaughter weights (100, 115, 130, and 145 kg BW).

For each slaughtered lot, the CI for the actual mean ($\bar{x}$) of the BW, and the BT were calculated based on the product between the standard deviation (Sx), and the two-tailed Z value for a 5% statistical significance ((1-α)/2), as a function of the square root of the number of animals (√n), as seen in equation 2:

$$CI = \bar{x} \pm Z_{((1-\alpha)/2)} * (S_x/\sqrt{n}) \quad (2)$$

Amplitudes of the CI obtained for each actual average of the BW and BT data were maintained for the predict averages with INRAPORC® and to those corrected by the BW and BT correction equations. The verified percentages of the BW, BT, and the actual averages that were contained in the CI were verified, and the mean deviations (MD) between the actual and predicted averages, and between the actual and corrected averages, were obtained for each slaughtered lot.

RESULTS AND DISCUSSION

The AL and RE animal groups from the PIEROZAN (2014) experiment had sample variation coefficients of 6.20% and 5.03%, and sampling sufficiencies of 5.91 and 3.90 animals per group (Equation 1); respectively, and in each group six animals were housed. System validations based on the predicted and actual data from a small group of pigs in laboratory conditions, and with RE feed management, presented BW intercepts of +4.542 kg, which were not significant (P = 0.10), and linear regression coefficients of + 0.925, which were significant (P < 0.01), with systematic error rates, and predicted data overestimated by 7.5%.

This BW overestimation was associated with the simulated energy partitions, as the system underestimates the use of the bodies reserves for maintenance and heat loss, and this consequently results in overestimations (VAN MILGEN et al., 2005). The system does not model the temperature effects on the energetic partitions and the thermal comfort range for finishing pigs, which is from 12 ºC to 18 °C (LEAL & NÃÃS, 1992). During the PIEROZAN (2014) experiment, 50 % of the average weekly temperatures were over 18 °C, and this contributed to increasing the actual energy expenditure for thermoregulation, thus reducing the energy partition for lipid and protein deposition, and consequently the actual BW.

Another possible source for rate systemic errors in the system BW predictions was the minimal ratio between the lipid and protein depositions (DL:DP). INRAPORC® is unable to calibrate, but varies with genotype, gender (QUINIOU et al., 1996), body weight (DE GREEF et al, 1992), and energy intake (MÖHN & DE LANGE, 1998).

For BT, the linear regression coefficient (+1.013) was not significant (P = 0.73), while the intercept (-2.37 mm) was significant ($P < 0.01$), presuming overestimated predictions (Table 1). This systematic, fixed-effect error was influenced by the initial lipid mass value of the RE animal group profile, which was possibly not the actual initial lipid mass value. This could be due to variations in the lipid depositions in the body, depending on genetics, age, and gender (KLOAREG et al., 2006). The system authors (QUINIOU & NOBLET, 1995) described the lipid deposition equations, considering variation from some genetic groups and different genders, but INRAPORC® uses a generic equation for its simulations.

Prediction calibration curves gave rise to correction equations for the predicted BW (Equation 3), and BT values (Equation 4):

$$BW_{correct} = 0.925{*}BW\ Inraporc + 4.54,\ (R^2 = 0.994) \quad (3)$$

$$BT_{correct} = 1.013{*}BT\ Inraporc - 2.37,\ (R^2 = 0.985) \quad (4)$$

F01 and F02 were assessed to determine if they had equivalent populations and could be considered as a single herd. They reported a similarity between their initial body weight averages ($P = 0.49$), and their population variations ($P = 0.84$). When considering the two farms as a single herd, the number of BT and BW observations increased from 4 and 5, to 8 and 10, respectively (Table 1).

When comparing the INRAPORC® predictions with the actual data from the pigs of the unified F01 and F02 for BW and BT, the intercepts ($P > 0.52$), and linear regression coefficients ($P > 0.15$) were not significant (Table 1). These results are favorable to system calibration extrapolation from a laboratory animal group to a commercial pig production system. However, for the BT, the unified herd (F01 and F02) showed significant differences

Table 1 - Intercept values (b_0), linear regression coefficients (b_1), and their respective probabilities for body weight and backfat thickness, average daily consumption, and the barrow population sizes, under the feed restrictions of the Pierozan (2014) experiments and for Farms 01 and 02.

	RE group Pierozan (2014)	F01-02 Oliveira et al. (2015)
Population (n)	6	192
DAFI (kg/d)	2.721	2.582
Initial age (days)	128	129
BWi (kg)	78.53 ± 3.95	80.68 ± 8.00
Observations BW-BT (n)	13-13	10-8
αTest-T F01-02 μ		48.51 %
αTest-T F01-02 σ		83.95 %
------Body weight (BW)------		
b_1	+0.93$^{(*)}$	+1.01
αb_1	0.46 %	87.05 %
b_0 (kg)	+4.54	+0.30
αb_0	10.33 %	95.77 %
αTest-T paired	0.03 %	25.58 %
------Backfat thickness (BT)------		
b_1	+1.01	+0.82
αb_1	73.04 %	14.48 %
b_0 (mm)	-2.37	+1.33
αb_0	0.33 %	52.19 %
αTest-T paired	0.00 %	0.02 %

RE group: animal group receiving restricted feed management; contemporary, and managed under the same environmental conditions as the group receiving the *ad libitum* feed management (AL); used to calibrate INRAPORC®; F01-02: farms 01 and 02 were considered as a single herd; DAFI: daily average feed intake (kg/d); BWi: initial body weight; Observations BW-BT: observations of the body weight and backfat thickness; αTest-T F01-02 μ: probability percentage of equal averages in the *t*-tests for the independent samples; αTest-T F01-02 σ: probability percentage for equal standard deviations in the *t*-tests for independent samples; b_1: linear regression coefficient; αb_1: probability percentage that the linear regression coefficient would be equal to 1.00, unity probability; b_0: intercept value; αb_0: probability percentage that the intercept would be 0, null probability; αTest-T paired: probability percentage that the paired data differences for the actual and predicted values of the BW or BT were equal to 0; $^{(*)}$ for $b_0 = 0$; b_1 assumes a value of: 0.9620 ($P < 0.0001$).

in the *t*-test ($P \leq 0.02$), influenced by the intercept fixed-effect error (-2.37 mm). This indicated that it is important to have a correction for the BT predicted values.

BW and BT data normality analyses using the Komolgorov-Smirnov method presented data distributions that did not have different normalities from the BW ($P > 0.41$) and BT ($P > 0.87$) (Table 2). The sample sufficiency was verified for the BW and BT, as in the single herd there were 192 animals and according to Eq. 1 the sampling sufficiency for the BW data was 40 animals, and for the BT it was 100. This information may be considered for future experiments that will use INRAPORC® for commercial populations.

Predicted BW and BT averages were corrected using the prediction calibration curves described by equations 3 and 4. The mean deviation between the actual and predicted averages for the BW data was +1 kg, whereas for the corrected means it was -4 kg (Table 3). This deviation between actual and predicted averages occurred due to the individual performance kinetics that were described by different population kinetics models (POMAR et al., 2003;

Table 2 - Actual average information predicted by INRAPORC® and corrected for body weight and backfat thickness, data variations, normality tests, and the characteristics of each lot of barrows slaughtered from the F01 and F02 farms.

Lot (Farm – slaughter weight)	Age (days)	Period (days)	Herd (n)	Actual Average	CV (%)	Norm. (p) %	InraPorc predicted average	Corrected Average
-----Body weight (kg)----								
F01-BWi	134	0	76	85.0 ± 7.1	8.4	99.9	85.0	85.0
F01-100	152	18	22	97.8 ± 8.4	8.6	95.2	98.3	95.6
F01-115	175	41	18	118.8 ± 9.2	7.7	84.0	120.0	115.6
F01-130	193	59	18	133.5 ± 11.2	8.4	99.0	133.3	127.8
F01-145	209	65	18	143.0 ± 12.0	8.4	94.8	147.8	141.3
F02-BWi	126	0	116	77.8 ± 7.3	9.3	96.5	77.8	77.8
F02-100	152	26	28	103.8 ± 9.9	10.2	94.0	101.6	98.5
F02-115	173	47	29	119.9 ± 10.5	9.6	93.7	120.4	116.0
F02-130	193	67	31	137.5 ± 10.4	9.6	41.1	137.9	132.2
F02-145	207	81	28	146.2 ± 10.2	8.3	53.1	148.9	142.3
----------------Backfat thickness (mm)----------------								
F01-100	152	18	22	13.8 ± 3.6	25.9	94.3	14.2	12.0
F01-115	175	41	18	14.7 ± 2.8	18.9	99.2	16.6	14.4
F01-130	193	59	18	16.6 ± 2.6	15.6	97.7	18.3	16.2
F01-145	209	65	18	17.6 ± 3.6	20.2	92.3	20.0	17.9
F02-100	152	26	28	12.6 ± 3.6	28.2	97.8	15.4	13.2
F02-115	173	47	29	16.7 ± 4.0	23.8	87.3	18.1	15.9
F02-130	193	67	31	17.8 ± 4.0	22.2	97.9	20.0	17.9
F02-145	207	81	28	18.6 ± 4.0	21.4	99.0	21.3	19.2

F1: Farm 01; F2: Farm 02; Slaughter weight: target weight at which animals lots were slaughtered; Lot: subgroup of animals slaughtered with respect to the farm number and slaughter weight range (Ei: F1-100); BWi: initial body weight; Age: animal age at slaughter or at the beginning of the test; Period: period of days that the animal lots remained under evaluation; Herd: Number of animals in each lot (n); CV%: Coefficients of variation for body weight or backfat thickness, percentage of the sample standard deviation and actual average; Actual average: actual average for the body weight or backfat thickness; Normality (p): data normality significance against the actual population average to slaughter weight using the Komolgorov-Smirnov test; InraPorc predicted average: predicted average body weight or backfat thickness values determined using INRAPORC®; Corrected average: average body weight obtained after the INRAPORC® prediction values were corrected. This correction was based on the prediction calibration curve (BW actual = 0.925 * BW InraPorc + 4.54 kg), or average backfat thickness obtained after the correction of the INRAPORC® prediction value, and this correction was based on the prediction calibration curve (BT actual = 1.013 * BT InraPorc – 2.37mm).

Table 3 - Actual values predicted by INRAPORC® and corrected for body weight and backfat thickness for each slaughtered lot from farms 01 and 02, after different periods of stay before slaughter. Averages of the confidence intervals for the predicted and corrected averages, using the confidence intervals obtained for the actual averages of each slaughtered lot.

Stay period of the lot on the farm before slaughter (days)	Unified herd farm 01-02 (n = 192)						
	Averages			Confidence intervals*			
	Actual	Predict	Corrected	Predicted		Corrected	
				IL	UL	IL	UL
	Body weight (kg)						
18	98	98	96	95	102	92	99
41	119	120	116	116	124	111	120
59	133	133	128	128	138	123	133
75	143	148	141	142	153	136	147
26	104	102	98	98	105	95	102
47	120	120	116	117	124	112	120
67	138	138	132	134	142	129	136
81	146	149	142	145	153	138	146
MD to actual average		1	-4				
% actual average in CI				100.00 %		75.00 %	
	Backfat thickness (mm)						
18	13.8	14.2	12.0	12.7	15.7	10.5	13.5
41	14.8	16.6	14.4	15.3	17.9	13.1	15.7
59	16.6	18.3	16.2	17.1	19.5	15.0	17.4
75	17.6	20.0	17.9	18.4	21.7	16.3	19.6
26	12.6	15.4	13.2	14.1	16.7	11.9	14.6
47	16.7	18.1	15.9	16.6	19.5	14.5	17.4
67	17.8	20.0	17.9	18.6	21.4	16.5	19.3
81	18.6	21.3	19.2	19.8	22.7	17.7	20.7
MD to actual average		1.9	-0.2				
% actual average in CI				25.00 %		87.50 %	

*: average confidence interval; Actual: actual population average for each slaughtered lot; Predicted: average predicted by INRAPORC®, based on the period of stay on the farm for each slaughtered lot; Corrected: corrected predicted average based on the prediction calibration curves obtained using the relationship between the actual and predicted averages of the animal groups when receiving the restricted feed management described by Pierozan (2014), for body weight: (BW actual = 0.925 * BW InraPorc + 4.54 kg), and for backfat thickness: (BT actual = 1.013 * BT InraPorc - 2.37 mm); IL: lower limit of the average confidence interval; UL: upper limit of the average confidence interval; MD to actual average: mean deviation from the predicted average or corrected for the actual average of the slaughtered lot; % actual average in CI: percentage of the real average values that were within the predicted or corrected average confidence intervals.

VAUTIER et al, 2013). INRAPORC® simulations consider a median animal ;however, there are animals that may have nutritional requirements above or below the simulated curve (KNAP, 2000; VAUTIER et al., 2013). By assuming the nutritional strategy with medium nutritional requirements for a population, it underfeeds animals with the highest performance potential and overfeeds the lower potential animals, thus reducing the population conversion rates and food efficiency (BROSSARD et al., 2006; VAUTIER et al., 2013), and the actual average population performance may be smaller than predicted.

The actual BW averages were (100%) within the CI of the predicted averages by INRAPORC® and 75% were within the CI of the corrected averages (Table 3). These data agree with the paired *t*-test results that the actual averages were similar to those predicted by the system (P = 0.26) (Table 1). For the BT data, 25% of the actual averages were contained in the CI predicted averages, and the *t*-test confirmed this as non- similar data (P = 0.02); however 87.5% of the actual averages were within the corrected averages of the CI.

The mean deviation between the actual and predicted averages was 1.9 mm, and between the actual and corrected averages was -0.2 mm (Table 3). These results agreed with the fixed-effect error previously observed, overestimating the BT predicted values (2.37 mm). The correction of these values with the equation obtained by the BT prediction calibration curve, presented satisfactory results, and most actual averages were within the CI of the corrected averages.

CONCLUSION

System calibrations using data from small groups of animals reared in laboratory conditions were effective at predicting the body weights of commercial pig populations, without needing to apply corrections to the predicted data. INRAPORC® overestimated the backfat thickness values, while the procedure for correcting the predicted data, based on the prediction calibration curves, was effective.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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