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Using Meta-analyses to Generate Alternative Prediction Equations for the Space Requirements of Finishing Pigs

J. R. Flohr, M. D. Tokach, S. S. Dritz[1], J. C. Woodworth, J. M. DeRouchey, and R. D. Goodband

Summary

Data from existing literature examining the influence of floor space allowance on the growth of finishing pigs were used to develop prediction equations for ADG, ADFI, and G:F. Two sets of databases were used. The first database included information from studies examining the influence of floor space allowance. The second database included the aforementioned literature, along with papers examining the impact of floor space after pigs were removed from the pen (topping). The first database included 27, 25, and 25 papers for ADG, ADFI, and G:F, respectively. The second database included 30, 28, and 28 papers for ADG, ADFI, and G:F, respectively. The predictor variables tested were floor space (m^2/pig), k (floor space, m^2/final BW, $kg^{0.67}$), initial BW (kg), final BW (kg), feeder space (pigs per feeder hole), water space (pigs per waterer), group size (pigs per pen), gender, floor type, and study length (d). A mixed linear model approach was used for model development, and floor space treatments within each experiment were the experimental units. Evaluations of models with significant terms were conducted using the Bayesian Information Criterion (BIC). The optimum equations to predict finishing ADG, ADFI, and G:F for the first database were:

$$\text{ADG, g} = 395.57 + (15{,}727 \times k) - (221{,}705 \times k^2) - (3.6478 \times \text{Initial BW, kg}) + (2.209 \times \text{Final BW, kg}) + (67.6294 \times k \times \text{Initial BW, kg})$$

$$\text{ADFI, g} = 802.07 + (20{,}121 \times k) - (301{,}210 \times k^2) - (1.5985 \times \text{Initial BW, kg}) + (11.8907 \times \text{Final BW, kg}) + (159.79 \times k \times \text{Initial BW, kg})$$

$$\text{G:F} = \text{Predicted ADG/Predicted ADFI}$$

The optimum equations to predict ADG, ADFI, and G:F for the second database were:

$$\text{ADG, g} = 337.57 + (16{,}468 \times k) - (237{,}350 \times k^2) - (3.1209 \times \text{Initial BW, kg}) + (2.569 \times \text{Final BW, kg}) + (71.6918 \times k \times \text{Initial BW, kg})$$

$$\text{ADFI, g} = 833.41 + (24{,}785 \times k) - (388{,}998 \times k^2) - (3.0027 \times \text{Initial BW, kg}) + (11.246 \times \text{Final BW, kg}) + (187.61 \times k \times \text{Initial BW, kg})$$

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G:F =Predicted ADG/Predicted ADFI

All multi-term models reduced the BIC values compared to individual term models. Data from 3 separate experiments examining the effects of floor space allowance on growth performance were used to evaluate the accuracy of the prediction equations herein and also previously developed prediction equations (Kornegay and Notter, 1984[2]; Powell et al., 1993[3]; and Gonyou et al., 2006[4]). Predicted values from equations reported herein improved model evaluation statistics compared to Kornegay and Notter (1984), and Powell (1993), and were comparable to predicted values by Gonyou et al. (2006), with improved root mean square error calculations that suggest more accurate predictions of growth rate. Between the equations developed from the databases, those from the second database more accurately predict growth performance at heavier BW ranges as well as the growth performance of finishing pigs remaining in a pen after pigs are removed.

Key words: finishing pig, floor space, prediction equation

Introduction

Reducing the floor space allowance per pig reduces their ADG and ADFI. Alternatively, when floor space per pig is reduced, production per unit of floor space increases. This leaves a challenge for producers to balance animal welfare and economic implications when determining the space allowance to provide. Also, with increases in market weights and the productivity of the breeding herd, more finishing pigs are fed for longer periods, suggesting that floor space allowance may be more limited than previously. Providing equations that accurately predict the impact of floor space allowance on growth will allow producers to establish a value per unit of floor space to optimize growth rate while efficiently reducing fixed facility costs per pig.

Early research examining floor space allowance effects on growth expressed floor space as ft^2/pig. The issue with expression of floor space as a constant area is that, as the animal grows, its need for space grows as well. Petherick (1983)[5] began to utilize the constant coefficient *k,* which is calculated by the equation k = floor space (m^2)/$BW^{0.67}$. This new tool allows the user to calculate floor space requirements based on an area that increases along with BW. However, one issue with the use of *k* is that it is assumes floor space increases at the rate of $BW^{0.67}$; to date, no one has tested this hypothesis.

Previous prediction equations developed by Kornegay and Notter (1984) and Powell et al. (1993) have been reported; however, the maximum weight of pigs used in studies to

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[2] Kornegay, E. T., and D. R. Notter. 1984. Effects of floor space and number of pigs per pen on performance. Pig News Info. 5:23–33.

[3] Powell, T. A., M. C. Brumm, and R. E. Massey. 1993. Economics of space allocation for grower-finisher hogs: a simulation approach. Rev. Agric. Econ. 15(1):133–141.

[4] Gonyou, H. W., M. C. Brumm, E. Bush, J. Deen, S. A. Edwards, R. Fangman, J. J. McGlone, M. Meunier-Salaun, R. B. Morrison, H. Spoolder, P. L. Sundberg, and A. K. Johnson. 2006. Application of broken-line analysis to assess floor space requirements of nursery and grower-finisher pigs expressed on an allometric basis. J. Anim. Sci. 84:229–235.

[5] Petherick, J. C., and S. H. Baxter. 1981. Modelling the static special requirements of livestock. Page 75 to 82 in Modelling, Design and Evaluation of Agricultural Buildings. Scottish Farm Buildings Investigation Unit, Bucksburn, Aberdeen.

develop these equations was 250 lb, well below current market weights. Gonyou et al. (2006) used non-linear statistical modeling to capture a broken line space requirement of pigs for ADG and ADFI based on the allometric coefficient *k*. To date, these equations are viewed as the most applicable, due to their transformation of the data into percentage changes in ADG and ADFI as the unit of analysis. While this analysis allowed for the removal of study-to-study variation, it may have led to non-normally distributed error terms. Additionally, when the researchers collected information for this database, they only included experiments that contained at least one treatment above the *k* coefficient of 0.030 and at least one treatment below 0.030, which may have limited the amount of available literature in the database and may have potentially biased the results. Advances in statistical modeling using mixed models have led to the ability to directly model effects of floor space on ADG and ADFI.

The objective of this study was to utilize data from existing literature to establish alternative prediction equations for ADG, ADFI, and G:F of finishing pigs. In addition, three separate floor space allowance studies, not included in the databases, were used to evaluate the efficacy of the prediction equations developed.

Procedures

A literature review was conducted to compile studies that examined the effects of floor space allowance on ADG, ADFI, and G:F of finishing pigs. The literature search was conducted via the Kansas State University Libraries, using the CABI search engine and the key words “floor space allowance” or “stocking density” and “finishing pigs.” Data were derived from both refereed and non-refereed publications, including theses, technical memos, and university publications. The final database resulted in publication dates from 1983 to 2014. Two databases were compiled from the data. The first database contained studies in which floor space allowance was examined without removing pigs from the pen. The second database contained papers from the first database along with papers that examined growth performance that followed pig removals from the pen.

To be included in the final databases, experiments had to: (1) allow pigs ad libitum access to feed and water; (2) report the information needed to calculate study length, initial and final BW, ADG, ADFI, G:F, feeder space (pigs per feeder hole), water space (pigs per waterer), and floor type (slatted, partially slatted); and (3) report SE or SD terms for treatment means. The initial screen yielded 36 publications. Papers were eliminated from the analysis for not allowing ad libitum access to feed and water (1 paper); failure to report means for ADG, ADFI, or G:F (1 paper); lack of a measure of variation (3 papers); or failing to report information associated with feeder space, water space, or group size (2 papers). The final database resulted in 29 papers with 110 observations for ADG and 27 papers with 102 observations for ADFI and G:F.

Trials that were conducted in wean-to-finish facilities were not included in the databases because floor space treatments were conducted during the growing period immediately after weaning. Citations and descriptions of studies utilized in the database are presented in Table 1. For papers that did not provide study length or final BW, the missing information was calculated by using ADG, initial BW, and either study length or final BW. For papers that reported F/G, the inverse proportions were used, and SEs for G:F were calculated by converting the SE from the F/G mean. The coefficient *k* was recalculated for each space treatment observation based on final BW of the growth period and the associated floor space allowance. Growth performance over the entire study length was utilized for each experimental unit in the database, except if floor space allowance was adjusted across phases. In those instances that reported individual phase performance, the growth periods associated with specific floor space allowances were used.

Flooring type (partially slatted or fully slatted concrete) used in each study was also accounted for in the prediction models. For some studies, which may have had multiple group sizes (pigs per pen) per floor space allowance observation, the smallest group size was assigned to the treatment observation. Water space was calculated as the number of pigs per waterer within a pen. For pens where a wet/dry feeder was used, then each feeder space was considered a waterer. Feeder space was calculated as the number of pigs per feeder hole within the pen. For treatments in which group size varied within floor space treatment, then the average water space and feeder space were calculated and assigned to the treatment observation. Gender was categorized as a potential predictor variable. Four papers presented floor space treatments for barrows, and four papers reported floor space treatments for gilts. All other papers either contained mixed gender pens (barrows and gilts) or reported main effect means without separating gender × floor space treatment interactions.

There were three separate experiments used to evaluate the regression equations and previously discussed in the literature. Data from these experiments were not included in the databases used in equation development. Procedures used for the validation experiments can be found in Thomas et al. (2015[6], Exp. 1 and 2) and Flohr et al. (2015)[7]. To accommodate the variation between the baseline predicted and actual performance, the difference between predicted and actual growth performance of pigs stocked at the highest floor space allowance was used to adjust the intercept of the prediction equations within each experiment or within each period in Exp. 3. This fixed adjustment amount was then used to adjust the growth performance of the pens at other floor space allowances within the same experiment or period (Exp. 3) comparison.

Statistical Analysis

The PROC MIXED procedure of SAS (SAS institute, Inc., Cary, NC) was used to develop mixed model regression equations used to predict ADG, ADFI, and G:F for finishing pigs based on the two separate databases. The method of maximum likelihood was used in the model selection to evaluate significance of fixed effect terms. Floor space treatment applied within each experiment was the experimental unit for modeling the equations and random effects of decade, paper within decade, and experiment within paper × decade interactions were used. The error between decades, papers within decades, and experiments within paper × decade interactions were partitioned using the

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[6] Thomas, L. L., R. D. Goodband, M. D. Tokach, J. M. DeRouchey, J. C. Woodworth, and S.S. Dritz. 2015. The effects of increasing stocking density on finishing pig growth performance and carcass characteristics. Report of Progress, http://newprairiepress.org/kaesrr/

[7] Flohr, J. R., M. D. Tokach, J. F. Patience, G. Gourley, J. M. DeRouchey, S. S. Dritz, J. C. Woodworth, and R. D. Goodband. 2015. Re-evaluating floor space allowance and removal strategy effects on the growth of heavy weight finishing pigs. Report of Progress, http://newprairiepress.org/kaesrr/

repeated statement. Covariance parameter estimates were different, emphasizing the use of these random effects in the model selection process. To account for variance in experimental design and replication across papers, weighted SEs were used in the model as discussed previously by St-Pierre (2001)[8]. Weighting SE terms resulted in a reduced residual covariance estimate signifying its value in the model fitting process. The statistical significance of including terms in the model was determined at $P < 0.10$. Further evaluation of models with significant terms was conducted based on the Bayesian Information Criterion (BIC). A model with a reduction in BIC of more than 2 was considered an improvement (Kass and Raftery, 1995)[9]. Throughout the selection process, studentized residual plots were observed to determine if quadratic or interactive terms needed to be tested in the model. The model was determined using a step-wise selection procedure starting with manual forward selection through individual predictor variables. Once a candidate model had provided the lowest BIC, then the method of residual maximum likelihood (REML) was used to obtain the estimate of the parameters of the candidate models. The adequacies of the candidate models were also examined by evaluating a histogram of the residuals for evidence of normality and plotting residuals against predicted values of Y (ADG, ADFI, and G:F of finishing pigs within each set of databases). Actual values were plotted against predicted values to evaluate the line of equality and determine if there was bias in the estimation. Residual plots were also used to investigate outliers. Any residual more than 3 standard deviations from the mean was deemed an outlier. Any residuals deemed outliers were reviewed to determine if they were biologically significant. As a result, three outliers for finishing ADG, ADFI, and G:F in both databases were removed from the analysis.

As a measure of model performance, the observed values from the model databases were regressed against the predicted values, and statistical calculations were performed. These calculations included correlation of determination (r^2), mean bias, bias correction factor (C_b), concordance correlation coefficient (CCC), root mean square error of prediction (RMSEP), model efficiency statistic (MEF), and the coefficient of model determination (CD). The r^2 values assessed precision of the model by identifying the proportion of variance in the observed values described by the predicted values. Values range from 0 to 1, with values closer to one suggesting better precision. The mean bias assesses model accuracy by subtracting the mean of observed values minus the mean of predicted values. Positive values suggest underestimation of the model values, while a negative value suggests overestimation of the model predicted values. The C_b value is a value from 0 to 1 assessing model precision by examining how far the regression line deviates from the slope of unity, with values closer to one suggesting better precision. The CCC, or reproducibility index, uses the correlation coefficient, mean bias, and the C_b to assess both model accuracy and precision. Values range from -1 to 1, with 1 or -1 implying perfect concordance or discordance. Similar to normal statistical models, the RMSEP evaluates the total variation between observed and model-predicted values. The MEF value is interpreted as the proportion of variation explained by the line $Y = f(X_1, X_2, \ldots, X_p)$. A value of 1 would indicate a perfect fit, and if the value is less than zero the model-predicted values are more variable than the observed values. Finally, the CD is a ratio if the total variance of the observed data to the square of the difference between

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[8] St-Pierre, N. R. 2003. Reassessment of biases in predicted nitrogen flows to the duodenum by NRC 2001. J. Dairy Sci. 86:344–350.

[9] Kass, R. E., and A. E. Raftery. 1995. Bayes Factors. J. Am. Statist. 90:773–795.

model-predicted mean and mean of the observed data. A ratio less than 1 suggests overestimation of the total variance, and a value greater than 1 suggests an underestimation of the total variance. These statistical calculations were also used to evaluate the prediction equations developed herein, along with those previously reported in the literature.

Results and Discussion

The range of values that make up ADG, ADFI, and G:F for the finishing databases are presented in Table 2. These values depict the floor space, feeder space, water space, floor type, and study length from finishing swine experiments throughout the literature. They also portray the range of growth performance and BW throughout experiments used to develop the models herein. When using the equations, the input variables should reside within these ranges. Model development processes were similar for both databases, and finalized models contained the same predictor variables.

For ADG models, increasing k appeared to increase ADG, and using k as a single predictor variable for both databases resulted in the lowest BIC value (1,033 and 1,221 for databases 1 and 2, respectively; Table 3); therefore, it was the first predictor variable selected for the models. When examining the studentized residuals resulting from the models ($\text{ADG}=k$) clear quadratic trends were evident suggesting that increasing k increased ADG but at a diminishing rate; thus, k^2 was added to the models that were significant predictors ($P < 0.001$) of ADG, and its inclusion lowered the BIC values (1,012 and 1,200 for databases 1 and 2, respectively). Including final BW appeared to be useful in the models ($P = 0.054$ and 0.013 for databases 1 and 2, respectively) because as final BW increased, ADG increased, and it also lowered the BIC values (1,009 and 1,195 for databases 1 and 2, respectively). Initial BW was included as a significant predictor ($P = 0.026$) in the first database, which reduced a BIC value (1,005), and as initial BW increased ADG decreased. However, for the second database, initial BW was not a significant predictor of ADG ($P = 0.233$). After examining the residuals of models it appeared that for observations with heavier initial BW, as k increased, predicted values continued to underestimate ADG, suggesting the need for a k × initial BW interactive term. Its inclusion increased ADG as k or as initial BW increased, and it was useful ($P = 0.006$ for database 1 and $P < 0.001$ for database 2) as a predictor of ADG and resulted in models with the lowest BIC values. The BIC values resulting from these final multivariable models were improved (BIC = 999 and 1,183 for databases 1 and 2, respectively; Table 4) compared to single-term models, which justifies their use to predict finishing ADG for the both sets of databases.

When examining the model fits to their databases (Table 5), it appeared the model had an excellent fit, with predicted values being only slightly overestimated, with mean biases of -1.3 and -1.6 g/d for databases 1 and 2, respectively. The coefficients of determination ($r^2 = 0.968$ and 0.949 for databases 1 and 2, respectively) suggested that almost 97% and 95% of the variation observed in the actual values were explained by the model-predicted values. This agrees with the MEF statistics (MEF = 0.967 and 0.948 for databases 1 and 2, respectively) that almost 97% and 95% of the variation associated with the responses were explained by the fitted model-predicted lines. Additionally, the bias correction factors ($C_b = 0.999$) were high, suggesting the regression lines were closely related to the lines of unity, and the reproducibility indexes were also high (CCC = 0.983 and 0.989 for databases 1 and 2, respectively), indicating strong agreement between the observed and model-predicted values. The coefficients of model determination were greater than 1 (CD = 1.08 and 1.13 for databases 1 and 2, respectively), suggesting that the model-predicted values underestimated the total variance in the observed values by approximately 8% and 13%. The RMSEP (20.08 and 28.68 g/d for databases 1 and 2, respectively) indicated that in both databases more than 93% of the errors associated with the models were random errors.

For ADFI models, increasing *k* appeared to increase ADFI, and using *k* as a single predictor variable resulted in the lowest BIC values (1,175 and 1,391 for databases 1 and 2, respectively); therefore, it was the first predictor variable selected for the models. When examining the studentized residuals resulting from the models, (ADFI= *k*), clear quadratic trends were evident for *k,* suggesting that increasing *k* increased ADFI, but at a diminishing rate. Thus, k^2 was added to the models as a significant predictor ($P < 0.003$), which lowered the BIC values (1,168 and 1,383 for databases 1 and 2, respectively). Final BW was then included as a significant ($P < 0.001$) predictor of ADFI, because ADFI increased with increasing final BW, and this reduced the BIC values (1,126 and 1,339 for databases 1 and 2, respectively). Initial BW was also a predictor ($P = 0.056$ and 0.007 for databases 1 and 2, respectively) of ADFI, because increasing initial BW decreased ADFI, which reduced the BIC values (1,123 and 1,332 for databases 1 and 2, respectively). Finally, similar to ADG, the inclusion of a *k* × initial BW interaction ($P < 0.001$) reduced the BIC to the lowest values, and with its inclusion in the models, increasing *k* or initial BW resulted in an increased ADFI. The resulting multivariable models had improved BIC values (1,118 and 1,317 for databases 1 and 2, respectively) compared to single-term models, which justifies their use for predicting finishing pig ADFI.

When examining the model fits to their databases, it appeared the model-predicted values were very close to actual values, with mean biases of -0.21 and 0.06 g/d for databases 1 and 2, respectively. The coefficients of determination ($r^2 = 0.981$ and 0.978 for databases 1 and 2, respectively) suggested that approximately 98% of the variation observed in the actual values were explained by the model-predicted values. This agrees with the MEF statistics (MEF = 0.981 and 978 for databases 1 and 2, respectively) that approximately 98% of the variation associated with the responses were explained by the fitted model-predicted lines. Additionally, the bias correction factors ($C_b = 0.999$) were high, suggesting the regression lines were closely related to the lines of unity, and the reproducibility indexes were also high (CCC = 0.990), suggesting strong agreement between the observed and model-predicted values. The coefficients of model determination were greater than 1 (CD = 1.04), suggesting that the model-predicted values underestimated the total variance in the observed values by approximately 4%. The RMSEP was 50.54 and 59.24 g/d for databases 1 and 2, respectively, and indicated that more than 98% of the error of the models was random error.

For finishing G:F models, using the predicted ADG divided by the predicted ADFI for both databases resulted in models that produced BIC values of 636 and 758 for databases 1 and 2, respectively. The 95% confidence interval on the coefficient for the predicted G:F was 0.9948 – 1.0030 for the first database, and 0.9949 – 1.0026 for the second database. In both cases, the coefficient of 1.00 was observed in the 95% confidence interval range, which indicates Predicted ADG/Predicted ADFI was useful as a predictor of G:F for the corresponding databases. When evaluating the fit of the G:F models to their databases, the mean biases were -0.0006 and -0.0007 for databases 1 and 2, respectively. The slight overestimations in G:F are due to the overestimations of ADG. The coefficients of determination ($r^2 = 0.986$ and 0.978 for databases 1 and 2, respectively) suggested that approximately 98% of the variation observed in the actual values were explained by the model-predicted values. This agrees with the MEF statistics (MEF = 0.986 and 0.977 for databases 1 and 2, respectively) that almost 99% of the variation associated with the responses are explained by the fitted model-predicted lines. Additionally, the bias correction factors ($C_b = 0.999$) were high, suggesting the regression lines were closely related to the lines of unity, and the reproducibility index was also high (CCC = 0.993 and 0.988 for databases 1 and 2, respectively), suggesting strong agreement between the observed and model-predicted values. The coefficients of model determination were greater than 1 (CD = 1.02 and 1.04 for databases 1 and 2, respectively) suggesting that the model-predicted values underestimated the total variance in the observed values. The RMSEP were 0.008 and 0.010, and both indicated that more than 96% of the models error was random error.

Evaluating prediction model fits to external data sets

After developing the prediction equations herein, their accuracy was evaluated using external datasets not within the current databases. The datasets that were used were Thomas et al. (2015) and Flohr et al. (2015). As part of the data validation, previously published prediction equations (Harper and Kornegay, 1984; Powell et al., 1993; and Gonyou et al., 2006) were compared as well. The equations were validated with two separate datasets; the first included data from Exp. 1 and 2 from Thomas et al. (2015), and the data from Flohr et al. (2015) from d 0 to 105 among treatments in which no pig removals occurred. The second validation dataset included the aforementioned data along with the growth performance of pigs following pig removals in the Flohr et al. (2015) study.

Results from the first external dataset are presented in Table 6. Coefficients of determination (r^2) suggested strong precision of all the equations, which is largely due to the intercept adjustments that were performed. However, MEF values from the ADG and ADFI models of Powell et al. (1993) and Harper and Kornegay (1984), along with the ADFI model of Gonyou et al. (2006), were lower than the corresponding r^2 values, suggesting those model-predicted values explained less variation than the models developed herein. Mean biases for ADG were improved for the equations developed herein and for Gonyou et al. (2006), compared to Powell et al. (1993) and Harper and Kornegay (1984). Average daily feed intake model mean biases were largely (more than 35 g/d) overestimated by the Powell et al. (1993) and the Harper and Kornegay (1984) models; whereas, models herein overestimated ADFI values by 16 and 13 g/d for the models from databases 1 and 2, respectively. The smallest observed mean bias for ADFI models was observed from the Gonyou et al. (2006) model (-3 g/d). All C_b and CCC values were above 0.90, suggesting strong precision and accuracy of the models to the observed data. Again, this is biased upward due to the use of the intercept adjustment for the equations. Root mean square error of prediction values suggest that the variance and bias were reduced the most using the models developed herein, whereas Gonyou et al. (2006) equations were intermediate, and the Powell et al. (1993) and Harper and Kornegay (1984) models resulted in the highest estimates for variance and bias. Coefficient of model determination ratios ranged from 0.91 to 1.05 for ADG models, suggesting either slight overestimations or underestimations of the total variance. For ADFI models, equations from Gonyou et al. (2006) and from Harper and Kornegay (1984) resulted in low CD ratios (0.78 and 0.84, respectively), suggesting overestimations of the total variances in the observed data. The G:F models developed herein and those by Powell et al. (1993) fit the observed datasets similarly.

Results from the second external dataset are presented in Table 7. In this evaluation, only the prediction equations developed from the second database (with pig removal studies) was evaluated and compared to the fit of other previously published prediction equations. Coefficients of determination (r^2) suggested moderate to strong precision of all the equations, which is largely due to the intercept adjustments that were performed. However, MEF values for the Powell et al. (1993) and Harper and Kornegay (1984) ADFI models were much lower than corresponding r^2 values, suggesting the model-predicted values explained less variation than the linear regression of the predicted values plotted against the observed values. Mean biases for ADG were similar across all equations. Average daily feed intake model mean biases were largely (more than 58 g/d) overestimated by the Powell et al. (1993) and the Harper and Kornegay (1984) model; whereas, models herein and from Gonyou et al. (2006) were slightly overestimated (5 to 8 g/d). All C_b and CCC values were above 0.71, suggesting strong precision and accuracy of the models to the observed data. Again, this is biased upward due to the use of the intercept adjustment for the equations. Root mean square error of prediction values suggest that the variance and bias were reduced the most using the models developed herein and from Gonyou et al. (2006) equations; whereas, the Powell et al. (1993) and Harper and Kornegay (1984) models resulted in the highest RMSEP values. Coefficient of model determination ratios ranged from 0.92 to 0.99 for previously published prediction equations for ADG and ADFI; however, values for the ADG model herein appeared to overestimate total variance (0.76), and for ADFI it appeared the model underestimated total variance (1.06). The G:F models developed herein and those by Powell et al. (1993) fit the observed datasets similarly.

To summarize the comparative model statistics information, it appears the models herein can be useful tools in estimating the impact of floor space allowance on finishing pig growth performance. In terms of the bias of predicted values, those resulting from the models herein were comparable to the fit of predicted values of Gonyou et al. (2006) and were improved compared to Powell et al. (1993) and Harper and Kornegay (1984). This is not very surprising, considering that the early models proposed by Harper and Kornegay (1984) and Powell et al. (1993) were limited in the sense that information was derived for pigs up to 250 lb, which is well below the input information observed from the evaluation experiments and below the common market weights today. Additionally, these were single, fixed effect models that did not account for random variances known to affect the results, similar to paper to paper variance, or variance observed on growth rates over time. The model-predicted values herein provided improved RMSEP calculations compared to predicted values from the Gonyou et al. (2006) equations, which means they are more accurate in predicting floor space effects on growth.

The previous equations derived from Gonyou et al. (2006) for ADG and ADFI are based on the allometric *k* coefficient, and the researchers concluded that responses to changing space were similar across a variety of BW. However, the models herein would argue that BW still influences the response to floor space allowance even when the *k* coefficient is accounted for in the model. This would also argue the point that the space requirement for pigs does not grow proportionally to the rate of $BW^{0.67}$ that is the basis behind the use of the coefficient *k*. This is illustrated in the sense that when BW increases in the model herein, reductions in ADG and ADFI are greater than the prediction equations performed by Gonyou et al. (2006). Additionally, the equations herein suggest that feed efficiency is also impacted by floor space allowance, which disagrees with the previous conclusion of Gonyou et al. (2006), who found there was not a significant relationship between floor space and feed efficiency.

The two databases were separated due to some thought that pigs remaining in a pen after pig removals benefit from additional floor space with compensatory gain. Others believe that the increase in growth performance is due solely to the added floor space allowance that results from pig removals. Thus, by presenting both sets of databases, users can decide which prediction equations to utilize, based on the operation. Figures 1 and 2 illustrate the predicted ADG, ADFI, and G:F of pigs across several BW ranges and provided varying floor space allowances. Both prediction equations react similarly at light BW ranges and over large BW ranges, but at heavier BW ranges it appears that predicted ADG is higher for the second database compared to the first. In turn, this results in G:F estimates higher for the second database compared to the first for heavier BW ranges. This is largely due to the increased information at heavier BW ranges found in studies that used removal strategies. We believe that the added information is more valuable to more accurately predict growth at heavier BW ranges when evaluating floor space allowance.

Application of prediction equations

Discrepancies in health status, genetics, and environment between farms could result in differences in the predicted values of equations herein and the actual growth rate. One method to adjust for these factors is to assume the shape and magnitude of the response are similar across these factors and adjust the intercept of the equations to provide farm-specific estimates. To do so, the actual growth rates of pigs stocked at a known floor space allowance at a known initial and final BW can be used to make the adjustment. The difference between the predicted and actual value of growth is then used to adjust the intercept of the equation. For instance, in Farm A, pigs from 50 to 110 kg stocked at a floor space of 0.65 m^2 demonstrated an ADG of 920 g/d and an ADFI of 2,490 g/d. Based on the stocking density and BW range, the predicted equations for ADG and ADFI herein from the second database would predict values of 839 g/d for ADG and 2,570 g/d for ADFI. As a result, the ADG was 81 g/d higher than the predicted value and ADFI was 80 g/d lower than the predicted value. The intercepts for the equations can be adjusted by adding the difference (ADG: $337.57+81=418.57$; ADFI: $833.41-80=753.41$). These adjusted equations can then be used to model different economic scenarios due to changes in floor space allowances.

In conclusion, floor space allowance is an important environmental factor that influences finishing pig growth. The regression equations herein provide good alternative estimates of ADG, ADFI, and G:F based on BW and *k* associated with finishing pigs provided varying floor space allowances. Compared to previous equations, the models herein were developed using general linear mixed models, from larger databases, and with additional information at heavier final BW than previously reviewed. These growth predictions can be used to assess the economic value of floor space allowance for swine production. A spreadsheet available online at www.ksuswine.org and described in Flohr et al. (2015) can be used to make predictions within a specific operation.

Table 1. Summary of papers used in the regression analysis to predict ADG and ADFI from varying floor space allowances in finishing pigs

First author, year	Source type[1]	Trials	Treatments	Gender[2]	Floor space allowances, m^2	Initial BW, kg	Final BW, kg[3]	k[4]
Harper and Kornegay, 1983	J	1	2	Mixed	0.43-0.78	22.7	91-98	0.021-0.036
Moser et al., 1985	J	2	Exp. 1: 3	Mixed	0.28-0.37	23.0	55.0	0.019-0.026
			Exp. 2: 3	Mixed	0.56-0.74	55.0	100	0.026-0.034
Edwards et al., 1988	J	1	4	Mixed	0.46-0.67	34.2	83-86	0.024-0.034
NCR-89, 1993	J	2	Exp. 1: 3	Mixed	0.56-0.93	52.8-52.9	114-115	0.024-0.039
			Exp. 2: 4	Mixed	0.56-1.11	54.2-54.9	96-102	0.026-0.050
McGlone and Newby, 1994	J	1	3	Mixed	0.56-0.74	59.0	100-103	0.026-0.032
Brumm, 1996[5]	J	1	3	Barrows	0.65-1.20	55.6	137-138	0.024-0.044
Brumm and Miller, 1996	J	3	Exp. 1: 2	Mixed	0.56-0.78	20.6	111	0.024-0.033
			Exp. 2: 2	Mixed	0.56-0.78	22.6	106-108	0.025-0.034
			Exp. 3: 2	Mixed	0.56-0.78	20.6	106	0.025-0.034
Ward et al., 1997	J	1	2	Mixed	0.56-0.79	27.2	97-105	0.026-0.035
Edmonds et al., 1998	J	1	2	Mixed	0.50-0.74	18.0	107-126	0.022-0.029
Hyun et al., 1998a	J	1	2	Mixed	0.25-0.56	34.7	53-57	0.018-0.038
Hyun et al., 1998b	J	1	2	Mixed	0.25-0.57	35.8	54-57	0.017-0.037
Gonyou and Stricklin, 1998	J	1	3	Mixed	0.58-0.94	25.0	95-99	0.027-0.043
Dritz et al., 1999	M	2	Exp. 1: 2	Mixed	0.61-0.69	29.3	98-99	0.028-0.032
			Exp. 2: 2	Mixed	0.61-0.69	98-99	116-117	0.025-0.029
Matthews et al., 2001	J	1	2	Mixed	0.56-0.81	51.0	104-110	0.025-0.035
Brumm et al., 2001	J	2	Exp. 1: 2	Mixed	0.56-0.78	20.0	109-111	0.024-0.033
			Exp. 2: 2	Mixed	0.60-0.74	22.0	110	0.026-0.032
Hamilton et al., 2003	J	2	Exp. 1: 2	Mixed	0.37-0.93	40.0	80.0	0.020-0.050
			Exp. 2: 2	Mixed	0.56-0.93	80.0	120-121	0.023-0.038
Edmonds and Baker, 2003	J	1	2	Mixed	0.56-1.12	49.0	118-126	0.023-0.044
Brumm et al., 2004	J	1	2	Barrows	0.55-0.74	30.0	107-109	0.024-0.032
Brumm, 2004	J	2	Exp 1: 5	Barrows or gilts	0.58-0.74	22-23	114-116	0.024-0.027
			Exp 2: 2	Mixed	0.58-0.74	30-31	122-125	0.023-0.029
Peterson, 2004	T	1	3	Mixed	0.61-0.74	34.0	113-116	0.025-0.031
DeDecker et al., 2005[6]	J	1	4	Mixed	0.65-1.30	106-113	122-126	0.026-0.052
Gonyou and Street, 2007	J	1	2	Mixed	0.52-0.78	37.0	93-95	0.025-0.037
Anil et al., 2007	J	1	4	Barrows	0.64-0.88	31.0	115-121	0.027-0.035
White et al., 2008	J	1	2	Gilts	0.66-0.93	88.0	106-111	0.029-0.040
Young et al., 2008	J	1	2	Gilts	0.77-1.13	38.0	127-128	0.030-0.044
Jacela et al., 2009[6]	M	2	Exp. 1: 3	Mixed	0.67-0.80	107-109	125-126	0.026-0.032
			Exp. 2: 5	Mixed	0.62-0.88	114-118	124-126	0.024-0.035

continued

Table 1. Summary of papers used in the regression analysis to predict ADG and ADFI from varying floor space allowances in finishing pigs

First author, year	Source type[1]	Trials	Treatments	Gender[2]	Floor space allowances, m^2	Initial BW, kg	Final BW, kg[3]	k[4]
Shull, 2010	T	2	Exp. 1:5	Mixed	0.21-0.44	24.0	45-50	0.016-0.032
			Exp. 2:5	Mixed	0.35-0.73	61.0	77-89	0.019-0.036
Potter et al., 2010	M	1	4	Mixed	0.59-0.76	28-29	120-126	0.024-0.030
Potter et al., 2011[6]	M	1	4	Gilts	0.84-2.09	117.0	139-144	0.031-0.075
Landero et al., 2014	M	1	6	Mixed	0.63-0.76	32.0	120-124	0.025-0.030

[1] J = journal; T = thesis; M = technical memo

[2] Mixed refers to floor space treatments applied to pens containing both barrows and gilts.

[3] For papers that did not report final BW, the study length, initial BW and ADG were used to calculate final BW. For papers that reported Final BW but not study length, then ADG, initial BW, and final BW were used to calculate study length.

[4] Coefficient k is the constant in the equation k = floor space (m^2)/$BW^{0.67}$. k was recalculated for each experimental unit based on final BW and floor space allowance.

[5] Two experiments were reported in the literature but only data from Exp. 2 were used in the analysis.

[6] Studies in which removing pigs to relieve stocking pressure and achieve floor space allowance treatments were conducted.

Table 2. Descriptive statistics for data included in prediction models

	Days	BW, kg		Feeder space[3]	Water space[4]	Group size[5]	Floor space, m^2	k[6]	ADG, g	ADFI, g	G:F
		Initial[1]	Final[2]								
Database without pig removal studies											
ADG[7]											
Mean	77.5	38.5	101.8	5.9	10.0	15.2	0.66	0.02959	815.1	---	---
SD	31.3	18.2	22.6	2.8	4.8	10.1	0.19	0.00670	110.7	---	---
Minimum	27.0	18.0	45.1	2.0	4.0	3.0	0.21	0.01640	600.0	---	---
Maximum	133.0	98.5	137.7	12.0	28.0	43.0	1.20	0.05000	1,077.0	---	---
ADFI and G:F[8]											
Mean	75.4	39.2	100.6	6.0	9.5	14.9	0.64	0.02916	---	2,440.0	0.339
SD	32.0	18.9	23.0	2.9	4.1	10.3	0.19	0.00681	---	365.2	0.066
Minimum	27.0	18.0	45.1	2.0	4.0	3.0	0.21	0.01640	---	1,450.0	0.240
Maximum	133.0	98.5	137.7	12.0	28.0	43.0	1.20	0.05000	---	3,227.0	0.537
Database with pig removal studies											
ADG[9]											
Mean	69.3	48.4	105.3	5.8	11.0	16.5	0.68	0.02998	832.2	---	---
SD	36.0	30.5	23.0	2.7	5.6	10.5	0.21	0.00700	125.9	---	---
Minimum	10	18.0	45.1	2.0	4.0	3.0	0.21	0.01640	600.0	---	---
Maximum	133.0	117.9	141.0	12.0	28.0	52.0	1.39	0.05200	1,170.0	---	---
ADFI and G:F[10]											
Mean	67.0	49.6	104.4	5.9	10.6	16.3	0.67	0.02963	---	2,516.0	0.336
SD	36.3	31.1	23.4	2.8	5.3	10.7	0.21	0.00713	---	397.1	0.064
Minimum	10.0	18.0	45.1	2.0	4.0	3.0	0.21	0.01640	---	1,450.0	0.240
Maximum	133.0	117.9	141.0	12.0	28.0	52.0	1.39	0.05200	---	3,370.0	0.537

[1] Refers to the BW of pigs at the beginning of the experiment.

[2] Refers to the BW of pigs at the end of the experiment.

[3] Number of pigs per feeder hole.

[4] Number of pigs per waterer.

[5] Number of pigs per pen.

[6] Coefficient k is the constant in the equation $k = \text{floor space } (\text{m}^2)/\text{BW}^{0.67}$.

[7] The final database represents 27 papers with 97 observations for the ADG database without pig removal studies.

[8] The final database represents 25 papers with 92 observations for the ADFI and G:F databases without pig removal studies.

[9] The final database represents 30 papers with 112 observations for the ADG database with pig removal studies.

[10] The final database represents 28 papers with 107 observations for the ADFI and G:F databases with pig removal studies.

Table 3. Single variable models used to predict ADG and ADFI for finishing pigs

Item	*k*[1]	Floor space, m^2	BW, kg Initial	Final	Days	Feeder space[2]	Water space[3]	Group size[4]	Gender[5]	Floor type[6]
Database without pig removal studies										
ADG										
Probability, $P <$	0.001	0.001	0.824	0.013	0.425	0.692	0.002	0.057	0.436	0.854
BIC[7]	1,033	1,047	1,110	1,102	1,109	1,110	1,110	1,100	1,109	1,110
ADFI										
Probability, $P <$	0.001	0.001	0.005	0.001	0.437	0.001	0.001	0.001	0.044	0.408
BIC	1,175	1,179	1,234	1,184	1,240	1,228	1,227	1,219	1,236	1,240
Database with pig removal studies										
ADG										
Probability, $P <$	0.001	0.001	0.629	0.005	0.230	0.356	0.003	0.010	0.559	0.831
BIC	1,221	1,234	1,302	1,292	1,301	1,302	1,294	1,296	1,303	1,302
ADFI										
Probability, $P <$	0.001	0.001	0.001	0.001	0.316	0.001	0.001	0.001	0.033	0.890
BIC	1,391	1,395	1,442	1,733	1,456	1,439	1,439	1,444	1,451	1,457

[1] Coefficient *k* is the constant in the equation $k = \text{floor space } (m^2)/BW^{0.67}$.

[2] Represents the number of pigs per feeder hole.

[3] Represents the number of pigs per waterer.

[4] Group size represents the number of pigs per pen.

[5] Gender for each database consisted of barrow, gilt, and mixed (barrow and gilt) information.

[6] Floor types observed for finishing databases were partially and fully slatted concrete flooring.

[7] Bayesian Information Criterion values were used to compare the precision of the model. Models that minimized Bayesian Information Criterion (BIC) within the database were used to select variables for initial model building.

Table 4. Regression equations generated from existing data for ADG, ADFI, and G:F for finishing pigs

Dependent variable	Models	BIC
Database without pig removal studies		
ADG, g	=395.57+(15,727*k)-(221,705*k^2)-(3.6478*Initial BW, kg) +(2.2090*Final BW, kg)+(67.6294*k*Initial BW, kg)	999
ADFI, g	=802.07+(20,121*k^2)-(301,210*k^2)-(1.5985*Initial BW, kg) +(11.8907*Final BW, kg)+(159.79*k*Initial BW, kg)	1,118
G:F	=Predicted ADG/Predicted ADFI	636
Database with pig removal studies		
ADG, g	=337.57+(16,468*k)-(237,350*k^2)-(3.1209*Initial BW, kg) +(2.5690*Final BW, kg)+(71.6918*k*Initial BW, kg)	1,183
ADFI, g	=833.41+(24,785*k)-(388,998*k^2)-(3.0027*Initial BW, kg) +(11.2460*Final BW, kg)+(187.61*k*Initial BW, kg)	1,317
G:F	= Predicted ADG/Predicted ADFI	758

Table 5. Evaluation of model fit to databases

Model	r^2(1)	Mean Bias, g/d[2]	C_b[3]	CCC[4]	RMSEP, g/d[5]	MEF[6]	CD[7]
Database without pig removal studies							
ADG	0.968	-1.32	0.999	0.983	20.08	0.967	1.08
ADFI	0.981	-0.21	0.999	0.990	50.54	0.981	1.04
G:F	0.986	-0.0005	0.999	0.993	0.0080	0.986	1.02
Database with pig removal studies							
ADG	0.949	-1.63	0.999	0.989	28.68	0.948	1.13
ADFI	0.978	0.06	0.999	0.988	59.24	0.978	1.04
G:F	0.978	-0.0007	0.999	0.988	0.0099	0.977	1.04

[1] Coefficient of determination (Neter et al., 1996). Values measure the fit of the residual variance and do not infer information from random effects in the model; therefore, they are higher than a simple fixed effect model.

[2] Mean bias was computed by subtracting the mean of observed values from the mean of the predicted values (Cochran and Cox, 1957). A negative value insinuates an overestimation.

[3] Bias correction factor (C_b) is a component of the CCC statistic that indicates how far the regression line deviates from the slope of unity (45°; Lin, 1989).

[4] Concordance Correlation Coefficient (CCC), also known as reproducibility index, assesses both the precision and accuracy of the model (Lin, 1989).

[5] Root mean square error of prediction (RMSEP) is used to measure the predictive accuracy of the model (Mitchell, 1997).

[6] Modeling efficiency statistic (MEF) is used as an indicator of goodness of fit (Mayer and Butler, 1993). A MEF value closer to 1 suggests better fit, and a value less than zero indicates that the model-predicted values are worse than the observed mean.

[7] The coefficient of model determination (CD) explains the proportion of the total variance of the observed values explained by the predicted data. The closer the CD value to 1 the better, with ratios over 1 insinuating model underprediction of total variance, and a ratio less than 1 suggesting an overestimation of the total variance by the model.

Table 6. Validation of available equations to predict floor space allowance effects on growth[1]

	Flohr et al.				
	Without pig removals	With pig removals	Gonyou et al.	Powell et al.	Harper and Kornegay
ADG					
r^2[2]	0.99	0.99	0.98	0.96	0.95
Mean bias, g[3]	-1.50	-0.63	-2.13	-8.50	-11.38
C_b[4]	0.99	0.99	0.99	0.98	0.96
CCC[5]	0.99	0.99	0.99	0.96	0.94
RMSEP[6]	4.03	3.86	6.15	11.81	14.86
MEF[7]	0.99	0.99	0.98	0.92	0.87
CD[8]	1.01	1.00	0.91	0.99	1.05
ADFI					
r^2	0.98	0.98	0.97	0.95	0.97
Mean bias, g	-15.50	-13.38	-2.88	-35.13	-46.25
C_b	0.99	0.99	0.99	0.98	0.97
CCC	0.99	0.99	0.98	0.96	0.96
RMSEP	31.32	29.71	43.52	53.81	58.02
MEF	0.97	0.97	0.94	0.92	0.90
CD	1.04	1.04	0.78	0.97	0.84
G:F[9]					
r^2	0.86	0.87	---	0.87	---
Mean bias, g	0.003	0.003	---	0.003	---
C_b	0.97	0.97	---	0.97	---
CCC	0.90	0.90	---	0.90	---
RMSEP	0.005	0.005	---	0.005	---
MEF	0.76	0.77	---	0.77	---
CD	0.79	0.81	---	0.81	---

[1] All predicted values were adjusted for each of the three experiment data sets by subtracting the predicted value from the observed value for the high floor space allowance treatment. That difference was added to all predicted values within the experiment.

[2] Coefficient of determination (Neter et al., 1996).

[3] Mean bias was computed by subtracting the mean of observed values minus the mean of the predicted values (Cochran and Cox, 1957). A negative value indicates an overestimation.

[4] Bias correction factor (C_b) is a component of the CCC statistic that indicates how far the regression line deviates from the slope of unity (45°; Lin, 1989).

[5] Concordance correlation coefficient (CCC), also known as the reproducibility index, assesses both the precision and accuracy of the model (Lin, 1989).

[6] Root mean square error of prediction (RMSEP) is used to measure the predictive accuracy of the model (Mitchell, 1997).

[7] Modeling efficiency statistic (MEF) is used as an indicator of goodness of fit (Mayer and Butler, 1993). A MEF value closer to 1 suggests better fit, and a value less than zero indicates that the model-predicted values are worse than the observed mean.

[8] The coefficient of model determination (CD) explains the proportion of the total variance of the observed values explained by the predicted data. The closer the CD value to 1 the better, with ratios more than 1 insinuating model underprediction of total variance, and a ratio less than 1 suggesting an overestimation of the total variance by the model.

[9] Gonyou et al. (2006) did not report an equation to predict G:F differences associated with floor space allowances, and Harper and Kornegay provided a prediction equation for F:G rather than G:F; therefore, both papers were not included in feed efficiency equation validation calculations.

Table 7. Validation of available prediction equations and those developed herein, from the database with pig removal studies, to predict floor space allowance effects on growth[1]

	Flohr et al.[2]	Gonyou et al.	Powell et al.	Harper and Kornegay
ADG				
$r^{2(3)}$	0.81	0.77	0.74	0.72
Mean bias, g[4]	10.00	-6.00	-6.12	-11.18
C_b[5]	0.98	0.99	0.99	0.99
CCC[6]	0.89	0.87	0.86	0.84
RMSEP[7]	35.64	35.64	37.42	39.81
MEF[8]	0.74	0.74	0.71	0.67
CD[9]	0.76	0.92	0.99	0.99
ADFI				
r^2	0.82	0.85	0.68	0.70
Mean bias, g	-5.18	-7.88	-63.00	-58.94
C_b	0.99	0.99	0.86	0.88
CCC	0.90	0.92	0.71	0.73
RMSEP	51.12	47.92	91.87	87.73
MEF	0.81	0.83	0.39	0.44
CD	1.06	0.99	0.97	0.94
G:F[10]				
r^2	0.89	---	0.86	---
Mean bias, g	0.005	---	0.005	---
C_b	0.98	---	0.97	---
CCC	0.93	---	0.90	---
RMSEP	0.009	---	0.01	---
MEF	0.84	---	0.79	---
CD	0.92	---	0.88	---

[1] All predicted values were adjusted for each of the three experiment data sets by subtracting the predicted value from the observed value for the high floor space allowance treatment. That difference was added to all predicted values within the experiment. For Exp. 3 each period within the experiment required an intercept adjustment.

[2] Equations developed from the database not containing pig removals were used.

[3] Coefficient of determination (Neter et al., 1996).

[4] Mean bias was computed by subtracting the mean of observed values minus the mean of the predicted values (Cochran and Cox, 1957). A negative value indicates an overestimation.

[5] Bias correction factor (C_b) is a component of the CCC statistic that indicates how far the regression line deviates from the slope of unity (45°; Lin, 1989).

[6] Concordance correlation coefficient (CCC), also known as reproducibility index, assesses both the precision and accuracy of the model (Lin, 1989).

[7] Root mean square error of prediction (RMSEP) is used to measure the predictive accuracy of the model (Mitchell, 1997).

[8] Modeling efficiency statistic (MEF) is used as an indicator of goodness of fit (Mayer and Butler, 1993). A MEF value closer to 1 suggests better fit, and a value less than zero indicates that the model-predicted values are worse than the observed mean.

[9] The coefficient of model determination (CD) explains the proportion of the total variance of the observed values explained by the predicted data. The closer the CD value to 1 the better, with ratios over 1 insinuating model underprediction of total variance, and a ratio less than 1 suggesting an overestimation of the total variance by the model.

[10] Gonyou et al. (2006) did not report an equation to predict G:F differences associated with floor space allowances, and Harper and Kornegay provided a prediction equation for F:G rather than G:F; therefore, both papers were not included in feed efficiency equation validation calculations.

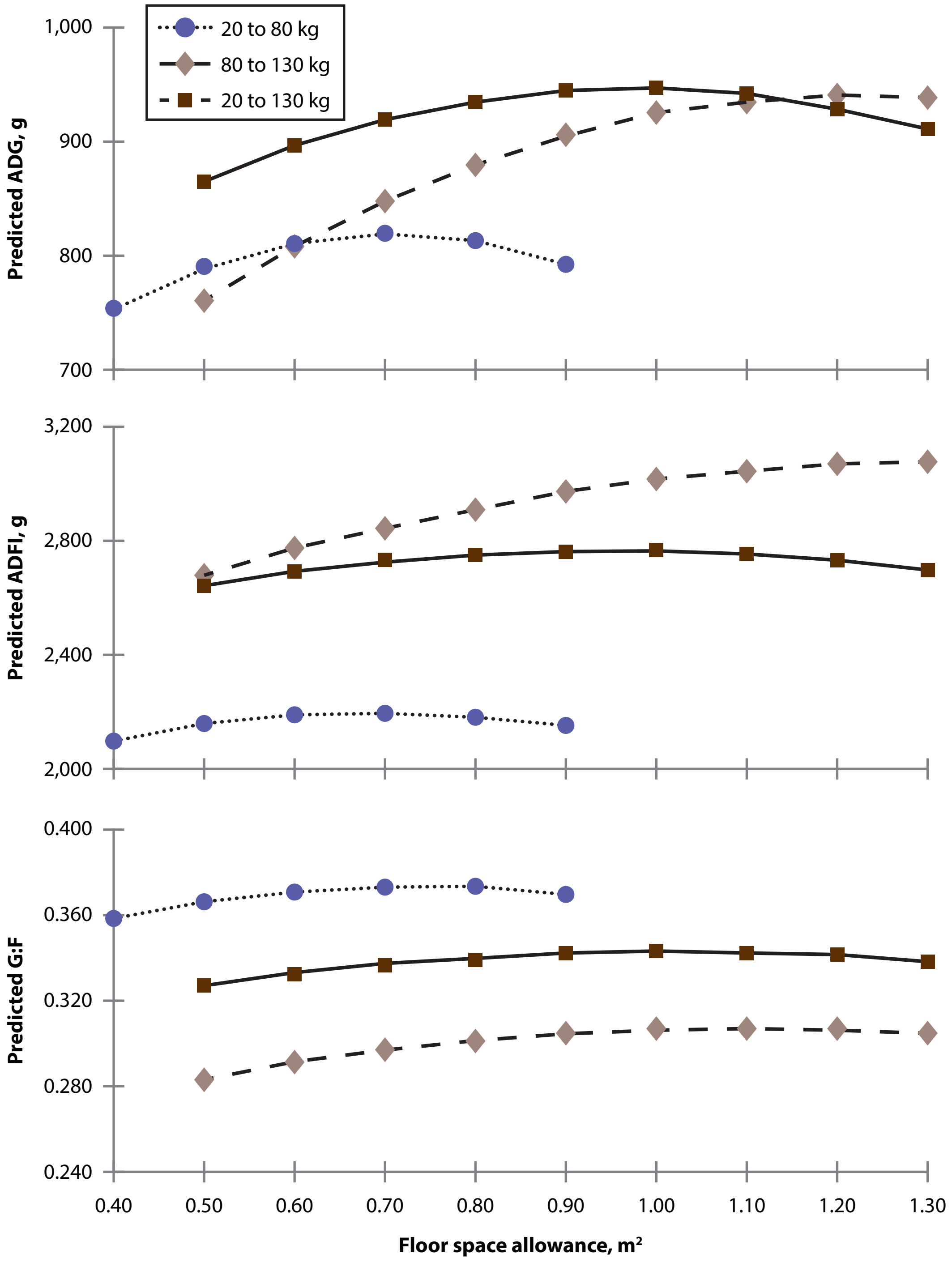

Figure 1. Predicted ADG, ADFI, and G:F of pigs from 20 to 80 kg, 80 to 130 kg, and from 20 to 130 kg as floor space allowance changes. The predicted ADG, ADFI, and G:F values derived from the first database without pig removal studies were calculated using the following models:

$$\text{ADG (g/d)} = (15{,}727 \times k) - (221{,}705 \times k^2) - (3.6478 \times \text{Initial BW, kg}) + (2.209 \times \text{Final BW, kg}) + (67.6294 \times k \times \text{Initial BW, kg}) + 398.57$$

$$\text{ADFI (g/d)} = (20{,}121 \times k) - (301{,}210 \times k^2) - (1.5985 \times \text{Initial BW, kg}) + (11.8907 \times \text{Final BW, kg}) + (159.79 \times k \times \text{Initial BW, kg}) + 802.07$$

$$\text{G:F} = \text{Predicted ADG/Predicted ADFI}$$

Where k = floor space m^2/final BW, kg 0.67; 1.00 m^2 = 10.764 ft^2

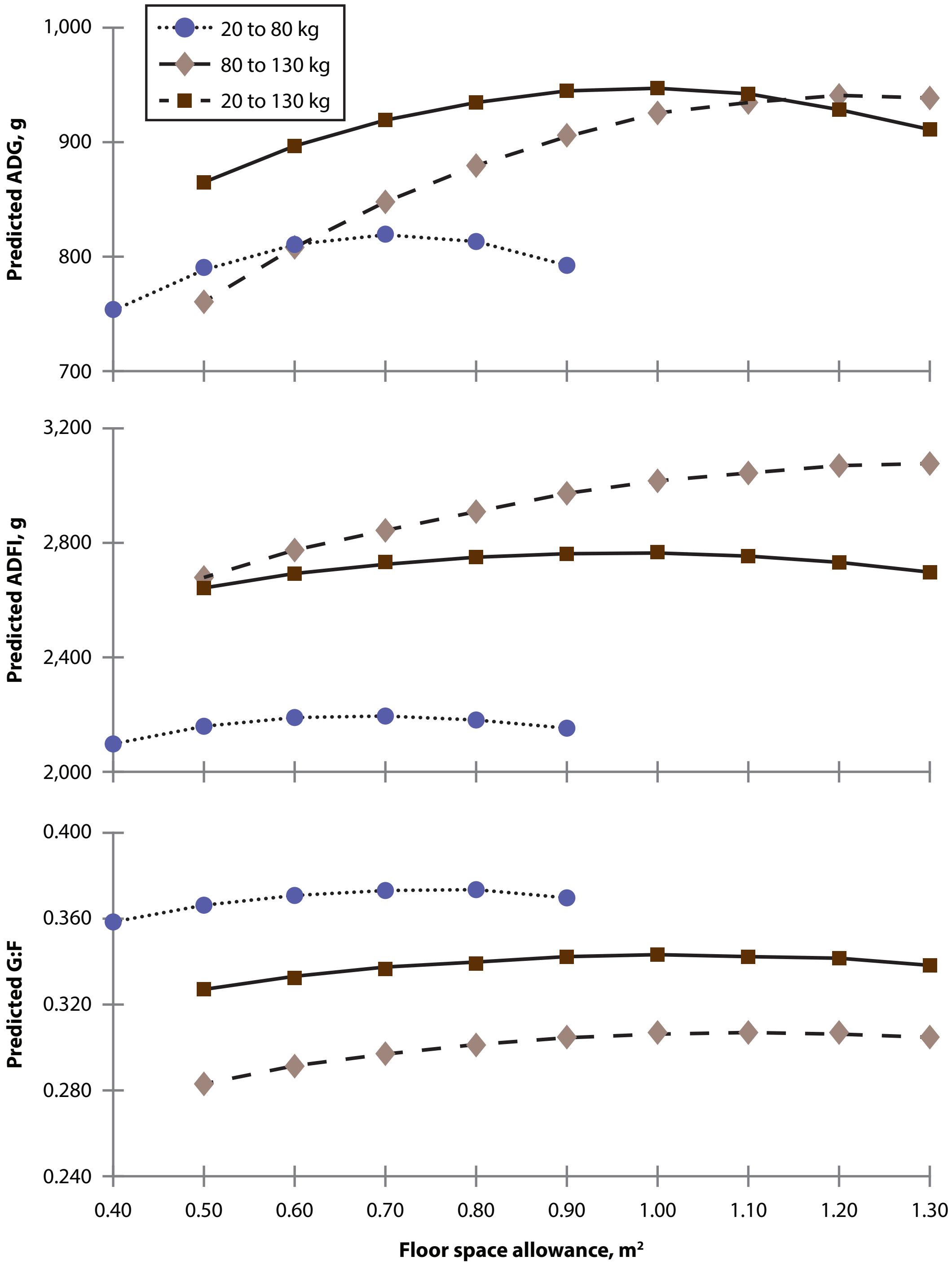

Figure 2. Predicted ADG, ADFI, and G:F of pigs from 20 to 80 kg, 80 to 130 kg, and from 20 to 130 kg as floor space allowance changes. The predicted ADG, ADFI, and G:F values derived from the second database with pig removal studies and were calculated using the following models:

$$\text{ADG (g/d)} = (16{,}468 \times k) - (237{,}350 \times k^2) - (3.1209 \times \text{Initial BW, kg}) + (2.5690 \times \text{Final BW, kg}) + (71.6918 \times k \times \text{Initial BW, kg}) + 337.57$$

$$\text{ADFI (g/d)} = (24{,}785 \times k) - (388{,}998 \times k^2) - (3.0027 \times \text{Initial BW, kg}) + (11.2460 \times \text{Final BW, kg}) + (187.61 \times k \times \text{Initial BW, kg}) + 833.41$$

$$\text{G:F} = \text{Predicted ADG}/\text{Predicted ADFI}$$

Where k = floor space m²/final BW, kg 0.67; 1.00 m² = 10.764 ft²