Technical note: A model to estimate individual feed intake of swine in group feeding¹

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ABSTRACT: In most animal growth experiments, groups of animals are housed within a pen. Occasionally, an individual animal shows a very different growth rate than its pen mates or dies during the experiment. When this happens, if pen feed intake (PFI) cannot be reestimated for the calculation of ADFI and feed efficiency, an observation will be lost from the data set. Therefore, we propose a model to estimate individual feed intake (IFI) of pigs in group feeding, with subsequent validation of the model using group feeding simulation studies. In the proposed model, the feed intake (FI) of each affected pen is partitioned into FI for maintenance (FIm) and FI for growth (FIg) for each animal within that pen. First, individual pig FIm for the period is calculated using the 1998 National Research Council estimation of ME for maintenance. Then, FIm for all pigs in the pen is summed. The difference between the summed FIm and the total PFI is that which supported growth in the pen. Next, FIg is calculated by apportioning the remaining feed equally to each unit of gain within the pen. Finally, the estimated IFI for the pig being removed from the pen is the sum of FIm and FIg for that pig; this FI estimate is subtracted from the original PFI to leave the new PFI for the remaining pigs. The validity of the estimated IFI is dependent on the accuracy of the maintenance energy equation and the energy analysis of the feedstuffs. In simulation studies, we compared the accuracy of the proposed method with 2 other methods. In simulation study 1, the proposed model showed better accuracy than at least one of the other methods during all tested periods (P < 0.001). In simulation study 2, the greater accuracy of the proposed method compared with 2 other methods was demonstrated again. Because calculation of IFI is relatively cumbersome, we developed a feed intake correction spreadsheet (FICS), an Excel spreadsheet containing macros for FI correction. All of the calculation procedures in the proposed model are included within the feed intake correction spreadsheet. The Excel file and instructions are being made available via a Web site.

Key words: Excel, feed intake, pig

INTRODUCTION

Multiple pigs are housed per pen in the majority of swine growth experiments. When an animal shows a very different growth rate than its pen mates due to illness or injury, or dies during the experiment, an observation would be lost from the data set if pen feed intake (PFI) cannot be reestimated for the calculation of ADFI and feed efficiency.

Computerized feed intake recording systems, such as the IVOG-station (de Haer et al., 1992), ACEMA-48 (Labroue et al., 1994), and FIRE feeders (Nielsen et al., 1995) enable monitoring of individual feed intake (IFI) in group-fed pigs. However, many swine research centers are not equipped with these computerized systems, mainly because they are costly.

Therefore, we propose a model to estimate IFI of pigs in group feeding situations and validate the model in 2 group feeding simulation studies. Additionally we present an Excel (Microsoft, Redmond, WA) feed intake correction spreadsheet (FICS) containing macros for IFI estimation and PFI correction, in order to allow users to easily calculate IFI and correct PFI.

INDIVIDUAL FEED INTAKE ESTIMATION MODEL

In the proposed model, feed intake (FI) of each affected pen is partitioned into FI for maintenance (FIm) and FI for growth (FIg) for each animal within that pen.
Daily metabolizable energy for maintenance (\( \text{ME}_m \)) is suggested in the NRC (1998) as

\[
\text{ME}_m, \ \text{kcal/d} = 106 \times \text{kg BW}^{0.75}, \ \ [1]
\]

where BW is the mean BW for the period of interest.

To calculate the amount of feed utilized for maintenance, Eq. [1] is modified, and the \( \text{FI}_m \) portion is described as

\[
\text{FI}_m, \ \text{kg} = (106 \times \text{kg BW}^{0.75} \times d)/\text{ME}_f, \ \ [2]
\]

where \( \text{ME}_f \) is the ME concentration in the feed, in kcal/kg, and d is the number of days in the period of interest.

Subsequently, \( \text{FI}_m \) for all pigs in the pen is summed. The difference between this sum and the total PFI is that which supported growth in the pen. Next, individual \( \text{FI}_g \) is calculated by apportioning the remaining feed equally to each kg of gain for each pig within the pen:

\[
\text{FI}_g, \ \text{kg} = (\text{PFI} - \sum \text{FI}_m) \times (\text{IBWG}/\sum \text{BWG}), \ \ [3]
\]

in which PFI is the total FI in the pen, in kg; \( \sum \text{FI}_m \) is the sum of maintenance FI for all pigs in the pen, in kg; IBWG is the individual BW gain, in kg; and \( \sum \text{BWG} \) is the sum of BW gain for all the pigs in the pen, in kg.

Individual FI for each pig for the period is then the sum of \( \text{FI}_m \) and \( \text{FI}_g \):

\[
\text{IFI}, \ \text{kg} = \text{FI}_m + \text{FI}_g. \ \ [4]
\]

The estimated IFI for the pig being removed (or considered for removal) from the pen is subtracted from the original PFI to leave the new PFI for the remaining pigs. The validity of the estimated FI is dependent on the accuracy of the maintenance energy equation (Eq. [1]) and the energy analysis of the feedstuffs. A limitation of the model is that it can only be used when there is no BW loss. When BW loss has occurred, or when there are changes in gut fill, tissue hydration, or tissue catabolism, aspects of the model are invalidated, which disallows the use of a common estimation of maintenance energy.

**MODEL VALIDATION**

All data used in these simulation studies were obtained from pigs used in experiments that were conducted under protocols approved by the University of Kentucky Institutional Animal Care and Use Committee.

**Simulation Study 1**

Growth data of 48 individually fed pigs [initial BW of 22.6 kg (SD = 1.5)] were used to create a simulation study. Pigs had been allowed ad libitum access to feed (3,440 kcal of \( \text{ME} \)/kg) and water. Individual pig BW and feed disappearance were recorded on d 21, 35, 49, and 56. Final BW of the pigs was 72.4 kg (SD = 4.0). Eighty pen combinations from these 48 pigs were made for model testing. Artificial “pens” were created by grouping 4 pigs (yielding 12 pens) or 6 pigs (yielding 8 pens). Groupings were each accomplished by 4 methods: complete randomization; randomized block, blocked by BW without regard to sex; randomized block, blocked by BW within sex; and randomized block, blocked by BW and sex and assigning equal numbers of barrows and gilts per pen. Within each of these “pens”, the known FI of the individually fed pigs was then pooled to create a “pen” feed intake; this “pen” feed intake and the individual pig BW were used to test the ability of the model to predict the individual pig feed intake.

**Simulation Study 2**

In the second simulation study, we used growth data of 48 individually fed pigs [initial BW of 24.8 kg (SD = 1.4)] to artificially create 12 pens. Pigs were allowed ad libitum access to feed (3,310 kcal of \( \text{ME} \)/kg) and water. Individual pig BW and feed disappearance were recorded on d 7, 14, and 21. Final BW of pigs was 43.8 kg (SD = 2.4). Artificial pens were generated using a randomized complete block design, with 2 barrows and 2 gilts in each pen.

**Individual Feed Intake Estimation**

In these simulation studies, the known FI of individually fed pigs was then pooled to create a PFI. A new IFI was subsequently calculated using the proposed model (Eq. [2 to 4]). Two alternative methods for calculation of IFI, the ratio method (RM) and the averaging
method (AM) were used as a comparison to the currently proposed model. In the RM, IFI was estimated by apportioning the PFI equally to each kilogram of BW gain within the pen, assuming that IFI was proportional to individual BW gain. The AM estimated IFI as a mean of PFI, assuming that IFI of pen mates were the same. Both of these methods have been used by researchers attempting to salvage a pen observation impacted by the loss of a pig within the pen (M. D. Lindemann, University of Kentucky, Lexington, personal communication).

Then, to measure the accuracy and precision of the IFI estimation, the difference between the actual recorded IFI of each pig and the estimated IFI was divided by the actual IFI and multiplied by 100 to give a percentage deviance for each pig for each correction method, and a mean deviance value was then computed for each pen. These data were then subjected to paired Student’s t-test within Excel for each method compared with the proposed method, with \( P < 0.05 \) being used as the level of statistical significance. Each pen was considered as an experimental unit.

**Results**

In simulation study 1, the accuracy of the proposed method for IFI estimation was better than the RM during all periods \( (P < 0.001) \) and was better than AM during d 0 to 21 and d 35 to 49 \( (P < 0.001; \text{Figure 1}) \). In simulation study 2, the difference between estimated and actual FI was numerically lowest in the proposed method during all the periods, with the proposed method showing more accurate IFI estimation than RM during d 14 to 21 \( (P < 0.01) \) and d 7 to 21 \( (P < 0.05) \), and better estimation than AM during d 0 to 14 \( (P < 0.01) \) and d 0 to 21 \( (P < 0.05) \; \text{Figure 2} \).

**FICS: AN EXCEL SPREADSHEET CONTAINING MACROS FOR FEED INTAKE CORRECTION**

The calculation of IFI using the proposed model is relatively time-consuming when done manually. Consequently, FICS, an Excel spreadsheet, was developed that allowed rapid calculation of IFI and corrected PFI when an animal dies or for potential outlier exclusion. The macro is written in Microsoft Excel XP using visual basic application. The FICS and instructions are made available to any user at http://www.uky.edu/ (last accessed Dec. 8, 2006).

**Figure 2.** Difference between actual and estimated feed intake (%) using different methods for individual feed intake estimation in simulation study 2. Data represent means ± SEM of 12 artificial pens created by pooling data from individually fed pigs in a variety of manners. *\( P < 0.05 \) and **\( P < 0.01 \) compared with the proposed method. Initial and final BW of the pigs was 24.8 and 43.8 kg, respectively.

**Figure 3.** A flow chart showing (A) the implementation of the feed intake correction spreadsheet (FICS) and (B) a sample screen of FICS. The FICS and instructions are available at http://www.uky.edu/Agriculture/AnimalSciences/swine/FICS.html.
To use FICS, users should click “enable macro” when the file opens. Clicking “Feeding Data” activates a window in which feeding information is input, including feeding period; amount of consumed feed per pen; ME of the feed, in kcal/kg; the number of pigs in the pen; and a pig identified as a potential outlier. After clicking the OK button, users can input the initial and final BW of the pigs for the period in the bordered blank cells. Selection of the Feed Correction button will calculate IFI of all of the pigs, and corrected PFI, and feed conversion ratio, as shown in Figure 3. Potential error warnings are included in the macro to avoid the accidental selection of the wrong pig for exclusion. An outlier confirmation procedure, which shows the difference of the outlier’s growth from its pen mates, is also included in the macro to be compared with the user’s criterion for exclusion.

The FICS is designed for swine growth research; however, it is also applicable to poultry and rodent growth trials, with modifications to the energy requirement for maintenance value and the exponent for metabolic BW. The value for adult rats is 114 kcal of ME/kg of BW0.73 (NRC, 1995), for hens is 100 kcal of ME/kg of BW (NRC, 1994), and for turkeys is 2.45 to 2.70 kcal of ME/g of BW0.67 (NRC, 1994); all of these values can vary slightly based on factors such as temperature and strain of the animal or bird.

An additional use of the model exists in nutrient (or additive) dose titration studies in group-fed animals. Response measurements may be influenced by the absolute nutrient amount consumed as well as the dietary nutrient concentration. The IFI information is needed to calculate amount of consumed nutrients per individual. The model will allow these calculations to be made as a method of further data assessment for potential inferences that may be more critically assessed with further experimentation.

Our simulation study demonstrates that the proposed model improves the accuracy of IFI estimation in group-fed pigs compared with the other methods. Investigators can readily apply this method in pig growth trials using the freely accessible FICS.

**LITERATURE CITED**


