PRODUCTION TOOL

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Developing farm-specific lysine requirements using accretion curves: Data collection procedures and techniques

James W. Smith II, MS, PhD; Mike D. Tokach, MS, PhD; Allan P. Schinckel, MS, PhD; Steve S. Dritz, DVM, PhD; Mark Einstein, MS; Jim L. Nelssen, MS, PhD; Robert D. Goodband, MS, PhD

Summary

Two methods of determining farm-specific lysine requirements are described. Using serial weighing and ultrasonic scanning of 40 pigs per gender at 3-week intervals throughout the entire growing-finishing phase, liveweight growth and protein and lipid accretion rates can be determined. Data are fit to two functions: a generalized nonlinear function for weight and protein mass, and a generalized exponential function for lipid mass. Lysine requirement estimates are calculated based upon the lysine needs for lean growth. The serial analysis can be used to determine daily lysine requirements (g per day, % of diet, or g:Mcal ME) and assess environmental impacts on growth from farm to farm. A second analysis uses mass weighing and scanning of 32 pigs per gender at five 3-week age intervals (384 pigs total) to determine protein and lipid accretion curves. These curves can then also be used to determine lysine needs. The mass method can be used to determine lysine needs as g per day, percent of diet, or g:Mcal ME similar to the serial method. These procedures allow for the assessment of farm-specific nutrient requirements, which can improve the efficiency of lean gain and reduce nutrient excretion. In addition, farm-specific data collected by these procedures can be used in the NRC swine growth model.

Keywords: lipid, protein, ultrasound, farm-specific

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Typically, lysine requirements of growing-finishing pigs are based on estimates determined on research farms in optimum environments. However such estimates can not take into consideration all conditions found in commercial growing-finishing facilities (e.g., disease status, temperature, crowding). Research has shown that growth and tissue accretion can be estimated by serial weighing and ultrasonic scanning of pigs throughout the growing-finishing period.[1] Protein and lipid accretion curves then can be modeled. Research from our team indicates that these procedures can be adapted to develop farm-specific growth rates, protein and lipid accretion rates, and lysine requirements.[2] In addition, these procedures can be used to develop user-defined whole-body protein accretion curves for use in the NRC (1998) swine growth model.[3] This paper will outline the data collection procedures and briefly describe the underlying principles involved in developing farm-specific growth curves and lysine requirements. Similar to the NRC[3] growth model, these procedures are based on observed growth rates. Two methods of obtaining the on-farm growth data and composition curves will be discussed:

- serial scanning, i.e., scanning the same pigs every 3 weeks from 23 kg (50 lb) to market, and
- mass scanning, i.e., scanning a sampling of pigs at different ages from 23 kg (50 lb) to market in 1 day.

Procedures

On-farm data collection

To calculate on-farm liveweight growth and component accretion curves, four types of data are needed:

- age of the pigs,
- tenth-rib fat depth,
- loin muscle area, and
- weight.

These data are then analyzed using several mathematical functions developed at Purdue University to determine farm-specific growth and accretion curves and, ultimately, lysine requirements. Therefore, pigs should be fed diets that are above the requirement to ensure that dietary lysine is not one of the factors limiting growth. The following sections will outline collection of these data, the analyses involved, and calculation of the lysine requirement as a lysine:calorie ratio.

Serial scanning

Real-time ultrasound (RTU) can be used to develop lean growth curves in commercial settings.[2] We use 40 pigs per gender to determine on-farm growth and composition curves. Pigs are weighed, tagged, and scanned ultrasonically within 1 week of placement in the finishing facility and every 3 weeks thereafter. Real-time ultrasound images are collected and interpreted by an NSIF-certified technician for tenth rib backfat depth and tenth rib loin muscle area. (A list of certified technicians is available from NSIF at 203 Polk Hall, Box 7621, North Carolina State University, Raleigh, North Carolina 27695–7621

JWS, MDT, RDG, JLN: Department of Animal Sciences and Industry, SSD: Food Animal Health and Management Center, Kansas State University, Manhattan, 66506–0201, Email: dritz@vet.ksu.edu; APS, ME: Department of Animal Sciences, Purdue University

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The pigs are chosen randomly from pens from each section of the barn to better assess the performance of pigs in the entire barn. Barrows usually are housed on one side and gilts on the other in barns housing both genders. We divide each side of the barn into four sections and chose 10 pigs from a pen in each section. When pigs are housed by a single gender, pigs are selected from one barn housing each gender. The whole barn is divided into four sections and 10 pigs selected from a pen in each section of the barn. These same 80 pigs are used for the entire analysis, so tagging pigs to maintain identity is essential.

Friesen, et al.,[4] suggested that 36 pigs per gender could be used at 20-kg (44-lb) intervals in the finishing facility to determine composition curves of growing-finishing pigs. This sample size calculation was based on a standard error of

- 2 g at 120 kg, and
- 1.5 g at 80 kg

for the protein accretion curves, which are similar to the standard error reported by Thompson, et al.[5] However, we choose to use 40 pigs per gender at 3-week intervals to ensure that enough data would be available to calculate the curves needed in case of lost ID tag, death loss, or injury. To schedule processing of pigs every 3 weeks for ultrasound measurements is much simpler from a management standpoint than predicting when the pigs have gained another 20 kg (44 lb).

Three keys to ensuring accurate prediction of growth and accretion rates and lysine requirements are:

- accurate age assessment,
- initiating scanning early in the growth period, and
- carrying pigs well past maximum market weight to ensure accurate assessment of growth and accretion rates in the late stages of finishing.

By initiating scanning early (< 25 kg or 55 lb) and carrying pigs to heavier weights (> 120 kg or 265 lb), the curves will better mimic the true growth of the pigs and will provide a better estimation of protein requirements. Researchers at Purdue University[5] showed that confidence bands were greater at the beginning (< 30 kg or 66 lb) and end of their experiment (> 110 kg or 243 lb). Therefore, using pigs that are lighter and heavier than those typically fed in the growing-finishing facility will allow more accurate predictions of liveweight growth and protein and lipid accretion rates and, therefore, amino acid requirements. Also, pigs used to develop on-farm growth and component accretion curves should be identified individually at birth, so that the actual age of the pig can be determined. Age is important because the weight curves are calculated on an age basis, and accurate age assessment will aid in attaining accurate liveweight curves. Week of farrowing often is used as birthdate. Pig age identification can also be accomplished with simple ear notching or tattooing.

Mass scanning

In an effort to decrease the time and money invested in determining growth and component accretion curves, techniques to scan a large number of pigs at a single time on an operation were tested. In this procedure, 32 pigs per gender were weighed and scanned based upon 3-week intervals of placement in the finisher, in essence mimicking the same intervals used in the serial procedure (0, 3, 6, 9, 12, 15, and 18 weeks in the finishing facility). Rather than following one set of pigs through the finishing facility, we mass scanned different age groups of pigs on the same day. The barns were divided into sections and pigs randomly selected as described in the section on serial scanning. Using these procedures, we were able to calculate accurate prediction equations for protein and lipid mass. However, liveweight curves determined via mass scanning were more variable. As a result, we have modified our procedures for mass scanning by using the proportional accretion rates of protein and lipid to model the lysine requirements.

As when making serial assessment of growth, it is important when using mass scanning to collect data from older/heavier pigs. One caution in collecting data from heavy pigs is not to collect data from groups that have been "topped" or partially marketed. This will bias the weight versus age and drastically decrease ADG in the latter stages of finishing. Because the remaining pigs will be the lighter ones, the average weight will not include the higher growth rate of the pigs already marketed from the barn.

Developing weight and composition curves

Either growth curves derived for serial weighing of a group of pigs during the entire growing-finishing period or a practical average daily gain (ADG) can be used to model the lysine requirements. These growth and composition data should be analyzed using statistical procedures developed at Purdue University.[5] Briefly, these procedures use a logarithmic transformation, and develop regression variables using the NLIN function of SAS.[6] More detailed descriptions of the statistical procedures can be found in Thompson, et al.,[5] Kyriazakis,[7] and Wagner, et al.[8]

The data are compiled in an Excel® spreadsheet, and estimations of birthweight, weaning weight, and weaning age are added to the data set. Liveweight data are fit to a generalized nonlinear function:

$$WT = WTM\left(1 - e^{\beta_0 + \beta_1 x + \beta_2 x^2}\right)$$

where:
WTM is an estimation of mature body weight of the pig, and
x is day of age.

The estimation of mature weight is determined statistically by iterative solving for various weights and is not based upon actual mature weights from the swine operation. The weight that yields the smallest residual standard deviation should be used to estimate the various regression variables to solve for liveweight versus age curves. Empty-body protein (EPB) and lipid mass can be calculated based on equations developed from serial ultrasound and slaughter of pigs at Purdue University.[5] Determine the empty-body protein mass predictions using the generalized nonlinear equation:

$$EBP = MTP\left(1 - e^{\beta_0 + \beta_1 x + \beta_2 x^2}\right)$$

where:

MTP is an estimation of mature protein content that is determined in the same manner as mature bodyweight.

Empty-body lipid mass can be predicted using the generalized exponential equation:

$$EBL = e^{\beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3}$$

Incremental daily lipid and protein gain should then be calculated for each day of age in the test period. Based on the incremental liveweight gain versus age curve, the daily lipid and protein gain (g per day) should be plotted versus liveweight. The daily protein and lipid gain can then be translated into lysine requirements, as described in the next section, or used as user-defined inputs in the NRC[3] growth model. The data manipulations described in this section are currently provided by scientists at Kansas State University and Purdue University (Contacts: Steve Dritz, dritz@vet.ksu.edu or Alan Schinckel, aschinck@purdue.edu).

Translation of growth and accretion curves into nutrient requirements

The estimates of liveweight growth and protein and lipid accretions derived from the statistical analysis can be used to determine the various components needed to calculate farm-specific lysine requirements. First, an energy requirement should be calculated based on tissue accretion, and then the daily lysine requirement determined. A lysine:calorie ratio can be calculated using these two estimates. A quadratic equation describing the lysine:calorie ratio curve can then be used to determine the appropriate ratio for the diets fed to pigs from the particular farm.

Daily metabolizable energy requirements are estimated based upon the energy required for growth and maintenance, as:[9]

$(0.4 \times \text{body weight}^{0.78})$ +
$(10.93 \times \text{protein accretion, kg})$ +
$(12.64 \times \text{lipid accretion, kg})$

Feed intake then is estimated as the metabolizable energy requirement divided by ME content of the feed. Alternatively, if actual feed intake is available, the actual data can be used. However, the actual intake data will have to be lowered by the estimated amount of feed wastage.

Maintenance digestible lysine requirement is calculated as $(0.0036 \times BW^{.75})$. Wang and Fuller[10] showed that the lysine required for maintenance is 3.6 mg per $kg^{.75}$. Apparent digestible lysine required for lean gain was determined by:

$$(0.066 \times \text{protein accretion}) \div 0.65$$

where:
0.066 is the lysine content of protein, and
0.65 is the efficiency of lysine utilization.

Several studies have shown that the lysine content as a percentage of total crude protein ranges between 6%–7%, with a majority showing a value of approximately 6.6%.[11–13] Whittemore[14] calculated the efficiency of post-absorptive lysine utilization to be 65%, a value that has been corroborated by Lee, et al.,[15] who estimated efficiency of utilization to be 67%. However, the efficiency of utilization ranges from 30%–70%,[15] making this the most controversial number in the analysis. Daily total lysine requirements were determined by:

$$\frac{\text{maintenance lysine requirement} + \text{lysine required for lean gain}}{0.80}$$

where:
0.80 equals the digestibility of lysine.

The digestibility of typical corn-soybean meal diets is 80%–85%. To determine lysine needs independent of the growth rate of the pigs, lysine:calorie ratios should be calculated by dividing total lysine requirement by the ME requirement. The lysine:calorie ratios can then be graphed at each weight, and a curvilinear trendline fit (using the quadratic trendline function in Microsoft™ Excel® to determine the mathematical equation that describes the curve at any weight in the range for which the values are derived. The percent lysine value then can be calculated by:

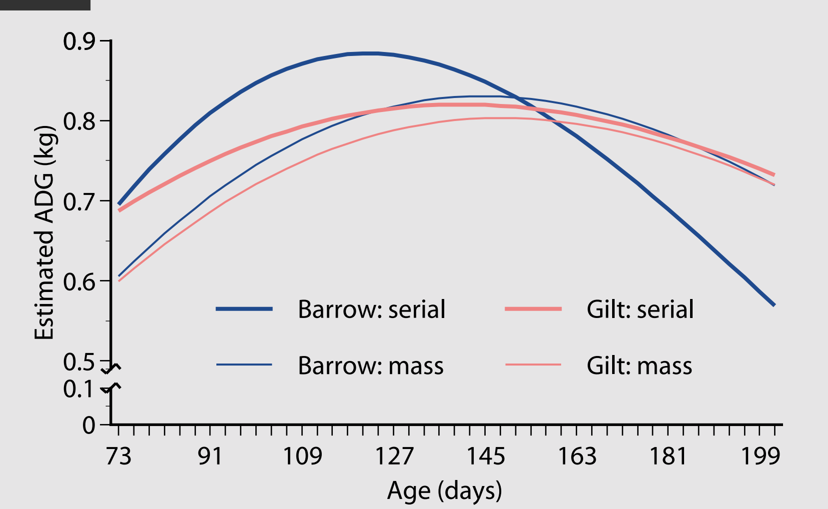
$$\text{lysine:calorie ratio} \times \text{energy content of the diet}$$

The predicted dietary lysine levels should then be compared to those values actually fed. Predicted values that are similar to the lysine values fed indicate that dietary lysine concentration may have been a growth-limiting factor.

Example data

Pigs on a farm in southwestern Minnesota were scanned to determine liveweight and component accretion rates using both serial (n = 80)

Figure 1



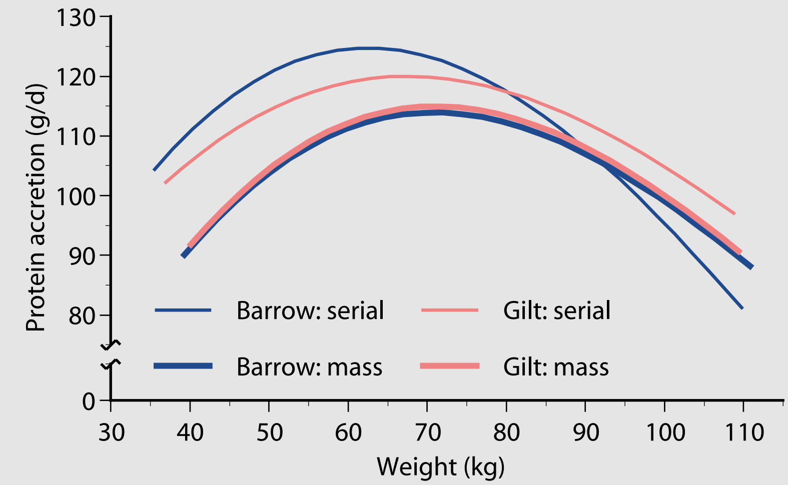
Liveweight growth of pigs estimated by serial and mass weighing and mass (n = 448) procedures (Figure 1). Predicted growth for all pigs from the serial procedure and for barrows from the mass procedure had similarly shaped curves. This intergroup difference in growth rates may have been caused by environmental factors.

Predicted empty-body protein and lipid accretion rates are shown in Figures 2 and 3. The protein accretion curves resulting from the two procedures appear to have similar shapes; however, the magnitudes and slopes are different (Figures 2 and 3). The curve for the barrows from the serial procedure maximized at approximately 125 g at 65 kg (143 lb) and decreased to approximately 80 g at 110 kg (143 lb). The curve generated for the barrows from the mass procedure was much flatter and was maximized at approximately 110 g at 80 kg (176 lb) bodyweight. Similarly, all four curves predicted for empty-body lipid accretion increased but differed in magnitude.

Because the main function of lysine is protein accretion,[16] the predicted lysine requirement curves (g per day) should mimic protein accretion curves, a phenomenon we observed in our sample data (Figure 4). Barrows from the serial procedure had the greatest predicted lysine requirement of approximately 17 g per day at 65 kg (143 lb) and also the lowest requirement of 11.5 g per day at 110 kg (220 lb).

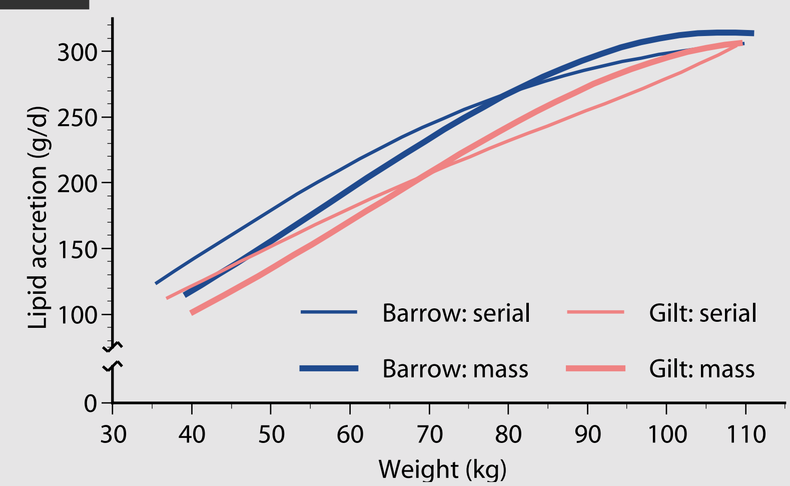
A more practical method for determining lysine requirement is to relate lysine to energy intake (Figure 5). The resulting lysine:calorie ratio (g:Mcal ME) reflects the proportional growth of protein and lipid. Even though the liveweight growth and protein and lipid accretion curves differed greatly between genders and scanning procedures, the proportional growth of protein and lipid was relatively constant. As a result, the predicted lysine:calorie ratios were very similar between the two procedures for each gender. Differences did exist between procedures but never exceeded 0.25 g:Mcal ME. In a typical corn-soybean meal diet, these differences equate to a change in lysine content of less than 0.08% of the diet. In our analysis, we began when pigs weighed approximately 30 kg (66 lb), and the predicted lysine:calorie ratios were 5.03 g:Mcal ME for barrows and 5.22 g:Mcal ME for gilts.

Figure 2



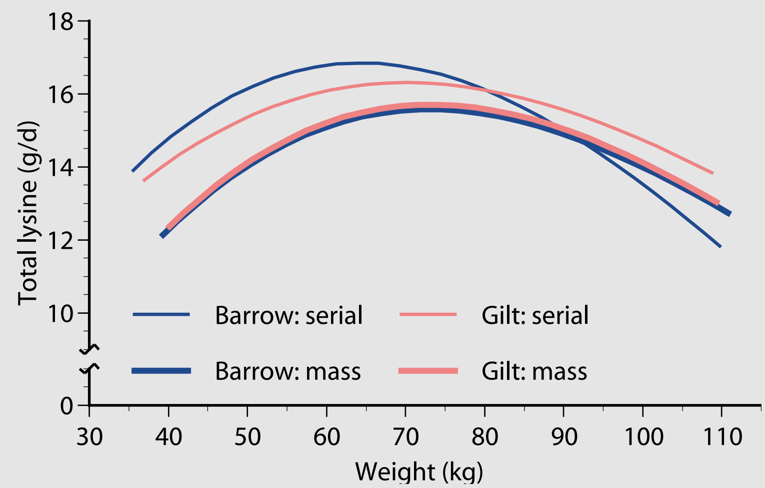
Empty-body protein accretion of pigs estimated by serial and mass scanning

Figure 3



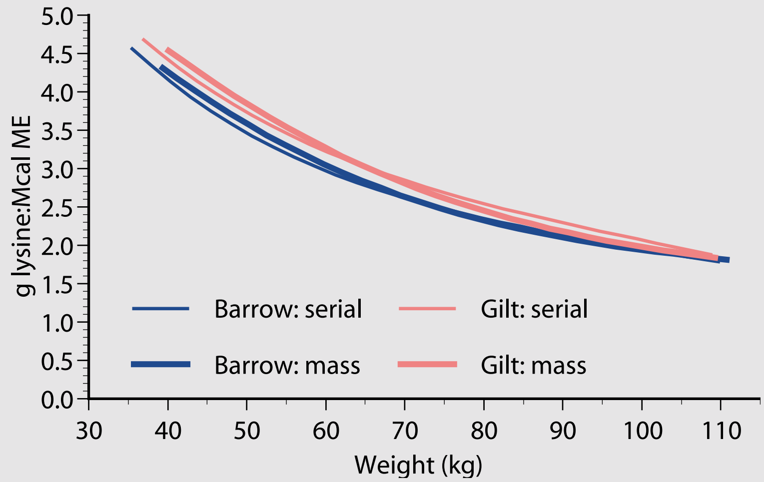
Empty-body lipid accretion of pigs estimated by serial and mass scanning

Figure 4



Daily total lysine needs, g per day of pigs estimated by serial and mass scanning

Figure 5



Total lysine needs, g:Mcal ME of pigs estimated by serial and mass scanning

Obviously, these concentrations are much greater than those provided in the diets fed when the analysis was conducted and illustrate the need to begin this analysis as early in the growth period as possible, because the confidence bands are much greater at the beginning and end of the growth curves. Therefore, the data are reported beginning at 40 kg (88 lb) bodyweight, even though the analysis began when pigs weighed 30 kg (66 lb). When the percentage of lysine in the diet was calculated from the lysine:calorie ratio and the energy content of the diet, the values also were very similar between the procedures for each gender.

Since the derived lysine:calorie ratio is curvilinear, a quadratic equation derived from the lysine:calorie ratio curve can be used to determine the appropriate lysine:calorie ratio for a given weight range. In this example, the equation is:

$$0.0003 \times \text{body weight}^2 - 0.0809 \times \text{body weight} + 7.0034$$

for the curves derived by the serial procedure for barrows. During specific phases, the average weight of the phase is used to determine the appropriate lysine:calorie ratio for formulating the diets. For example, using the estimates of lysine:calorie ratio from Table 1, diets designed for barrows weighing 50–70 kg (110–154 lb) would be formulated to contain 2.9 g lysine:Mcal ME, the value determined for 60-kg (132-lb) pigs.

These procedures can be used to meet several objectives of the swine practitioner or nutritionist. If the objective is to quantify environmental differences from farm to farm or estimate lysine requirements on a g-per-day basis, then serial scanning can be used. If the objective is to determine only lysine requirements on a g:Mcal ME basis, then protein and lipid accretion rates can be determined by mass scanning. The lysine:Mcal ME ratio then can be calculated using estimates of daily liveweight gain. The data derived from the described procedures can be used by swine practitioners as an educational tool for themselves and their clients to better understand the quantitative biology of pig growth. The quantitative biology can then be transformed into information for fine tuning nutrition programs on the farm.

Table 1

Predicted lysine: g per day, % of diet, and g:Mcal ME using serial and mass scanning[a]

	Lysine, g/d		g lysine:Mcal ME		Lysine, % of diet	
Weight, kg	Serial	Mass	Serial	Mass	Serial	Mass
Barrows						
45	15.72	13.16	3.67	3.71	1.22	1.23
60	16.91	14.69	2.91	2.85	0.96	0.94
75	16.41	15.36	2.44	2.25	0.80	0.74
90	14.83	15.20	2.11	1.90	0.70	0.63
105	12.55	14.32	1.85	1.69	0.61	0.56
120	9.75	12.96	1.59	1.60	0.52	0.53
Gilts						
45	14.92	13.96	3.96	4.05	1.31	1.33
60	16.08	15.31	3.19	3.11	1.04	1.03
75	16.23	15.55	2.65	2.49	0.87	0.82
90	15.51	14.88	2.27	2.08	0.75	0.69
105	14.14	13.47	1.94	1.82	0.64	0.60
120	12.39	11.61	1.63	1.65	0.54	0.54

a To calculate the percentage lysine in the diets, dietary energy values of 3.3 Mcal ME/kg was used. Actual total dietary lysine:calorie ratios (g:Mcal ME) fed during the data collection period were 3.3, 2.9, 2.7, and 2.3 g:Mcal ME for gilts and 3.1, 2.5, 2.0, and 1.8 for barrows from 34–57, 57–77, 77–95, and 95 kg to market.

Implications

- Guidelines are presented for determining farm-specific accretion curves.
- Serial or less expensive mass ultrasound scanning data collection procedures can be used.
- The farm-specific accretion curves can be used in the NRC swine growth model.
- Observed growth performance is used to determine lysine requirements.

Acknowledgements

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