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How to Conduct On-Farm Swine Feed Trials

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Introduction

We suggest that pork producers adopt a "best cost" feeding program tailored to the operation and based on sound nutritional principles. Feed cost per pound of gain is a major item separating high and low profit pork producers. University and feed industry personnel provide information to help producers develop an appropriate feeding program for their operation; however, sometimes that information is inadequate. In that event, a feed trial may be conducted on the farm to determine which feed is "best."

Caution! A feed trial that is expected to yield valid results requires attention to details. A careless approach will produce misleading results. Even a carefully conducted trial that does not use sound statistical principles may produce misleading results. Furthermore, money may be wasted if the results are deceptive. The key to conducting a meaningful trial is to:

1) minimize differences in pig performance that could be caused by factors other than the feed, and

2) provide a sound basis for ensuring that the results are reputable and valid for use.

The purpose of this publication is to provide fundamental information that must be understood before attempting to conduct a feed trial. Procedures to improve the reliability of farm trial results will be discussed. The concepts and procedures described here are valid for most situations involving a comparison of two feeds. Any trial involving more than two feeds raises issues that are beyond the scope of this publication. Those issues are covered in university statistics courses on design and analysis of experiments.

The most practical feed trials for producers to conduct are those involving growing pigs (weaning to about 50 lb and (or) 50 lb to market). Feed trials involving the breeding herd are difficult for many producers to conduct because adequate replication is difficult to achieve. (For example, to accurately detect a one-half pig per litter difference between sow feeds, 337 sows are needed per feed type.)

To illustrate some points, assume a producer wants to compare two nursery feeds. One feed is the control (the one currently used) and the other one is the test feed.

Trial Procedures

Weigh Pigs and Feed

A reliable set of scales to weigh pigs and feed is essential. Estimating pig weight by sight and feed use by volume is unreliable and therefore unacceptable. Use the same set of scales for the duration of the trial. Be sure they are calibrated before each use.

If feed is handled in bags and bag weight is uniform (less than 2 percent variation in weight between bags of feed), record the number of bags used during the trial. At the end of the trial, subtract the weight of feed remaining in the feeders to determine feed use.

Pigs should be weighed individually at the beginning and end of the trial. If a pig dies during the trial, and individual pig weights were collected, data can be adjusted.

Understand and Manage Variability or Chance Variation

Despite your best efforts to feed and manage littermates alike in the nursery or grower, their growth performance will not be exactly the same. That's because factors that you cannot explain or anticipate influenced their growth. Such variation occurs in every feed trial; understanding and managing this variation is important.

To aid the understanding of the concept of variability or chance variation, obtain five people and one coin. Assume the following:

1) heads denote the test feed,
2) tails indicate the control feed,
3) the decision on which feed is best will be based on the ratio of heads-to-tails after flipping the coin 10 times, and
4) the control and test feeds are identical.

Ask each person to flip the coin 10 times and record the number of heads and tails. How many people recorded five heads and five tails indicating there is no difference between the feeds? It is unlikely that everyone did. Some individuals likely recorded more heads than tails; others recorded more tails than heads. Therefore, some individuals were provided misleading information because of chance variation.

The relative amount of chance variation is commonly measured in feed trials through the coefficient of variation (CV). This is calculated as:

Coefficient of Variation (CV) =
Standard deviation ÷ Treatment mean x 100

The CV for growth performance traits is lower than that for reproductive traits (*Table 1*). A high CV makes differences between feeds harder to detect, while a smaller CV makes it easier to find differences. The large range in the CV for many of the traits shown in *Table 1* indicates that it is best for producers to determine their own farm's CV; otherwise, large errors are possible in determining the amount of replication needed in a trial at a particular farm.

Have Adequate Replication

Replication means observing at least two pens of pigs per feed type. Suppose only two pens of pigs were available to conduct the feed trial. The results of the trial showed that pigs fed the test feed outperformed those fed the control. Should we conclude that the test feed is superior? No. We cannot be certain that the difference in pig performance was due to the feed. It could have been due to other factors; for example, a malfunctioning waterer in the control pen or chance variation.

Having only one pen of pigs per feed type in a trial may cause misleading results. Replication is important

Table 1. Summary of range in coefficients of variation (CV) in swine production traits reported in various research trials[a].

Trait	*No. of Trials*	*Range in CV, %*
Sows		
Litter size at weaning	8	5.3 to 39.1
Litter weight at weaning	6	11.7 to 32.7
ADFI[b] of lactating sows	9	13.4 to 29.7
Wean-to-estrus interval	8	12.1 to 153.0
Nursery pigs		
ADG[b]	7	2.8 to 13.9
ADFI	7	3.9 to 14.5
G:F[b]	7	1.6 to 22.1
Growing-finishing pigs		
ADG	7	2.4 to 4.5
ADFI	7	1.9 to 4.1
G:F	7	1.0 to 6.9

[a]Johnston, L.J., A. Renteria and M.R. Hannon. 2003. Improving validity of on-farm research. *Journal of Swine Health Production.* 11(5):240-246.
[b]ADFI: average daily feed intake; ADG: average daily gain; G:F ratio of gain to feed.

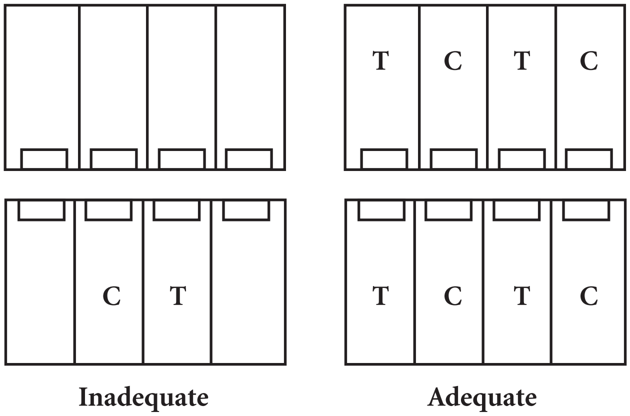

Figure 1. Example of inadequate and adequate replication of control (C) and test (T) feeds.

to minimize mistakes and ensure correct conclusions. In other words, each feed type must be provided in more than one pen of pigs *(Figure 1)*. Otherwise, the trial is not valid.

Previously we used the example of a coin flip to describe the concept of variability or chance variation. We will refer back to that to demonstrate the importance of replication. Recall that we asked how many people recorded five heads and five tails, indicating there is no difference between the feeds. It is unlikely that everyone did. Some individuals probably recorded more heads than tails; others recorded more tails than heads. Therefore, some individuals were provided misleading information. Averaging the results should reveal that about five heads and five tails were obtained, which indicates the feeds are similar. All trials have some element of chance variation. Replication reduces errors caused by chance variation.

How does chance get involved in a feed trial? If we have 20 pigs and randomly assign 10 to each pen, we expect to get an equal sample of similar pigs in each pen. But like the coin flip, it seldom comes out the way we expect. However, if we have several pens, on average, pigs assigned to each feed type should be similar. In this case, it is more likely that differences we observe result from *real* differences between feed types and not merely from luck or chance.

Table 2 provides guidelines for the number of pens per feed type required to detect a difference between two feeds with a reasonable degree of confidence. These guidelines allow producers to be 95 percent accurate when making conclusions about two feeds.

For example, if you wish to detect a 15 percent improvement in daily gain of nursery pigs (approximately 0.1 lb per day) and the CV is assumed to be 5 percent, you will need to have a total of four pens per feed type in the trial (*Table 2*). Fewer pens will decrease your ability to accurately detect a 15 percent difference between two feeds. Smaller improvements in performance may be economical; however, more replications are necessary to be sure you chose the correct feed.

If the number of pens per feed type requirements cannot be met at one time, repeat the trial over time using successive groups of pigs. Be sure to have the same number of pens available for each feed type during each time period. Also reassign feed types to pens before repeating the trial. (See the section on selecting proper pens.)

Two pens sharing the same feeder do not constitute two pens or two replications for feed trial purposes — they must be considered as one pen (i.e., there is no replication). Also, even if a barn houses 1,000 pigs in 40 pens and you provide the same feed to the entire barn, you have only one pen per feed type (i.e., there is no replication).

Individually penned animals fed separately from other pigs can be counted as replicates. For example, a farrowing room that contains 24 crates could be used to test two feeds and provide 12 sows or replications per feed type.

One issue many producers face is how to conduct the trial appropriately without causing major disruptions in daily operations. Let's assume a producer has a growing-finishing facility containing several pens and one automated feed delivery system. While it would be best for trial purposes to provide the control feed in one-half of the feeders and the test feed in the other half, the

Table 2. Number of pens needed per feed type for nursery and growing-finishing pig feed trials[a].

	Differences from control feed to be detected, %					
CV,%	*5*	*10*	*15*	*20*	*25*	*30*
2	5	3	2			
5	23	7	4	3	3	3
10	85	23	11	7	5	4
16	216	55	25	15	10	8
20	337	85	39	23	15	11

[a]Berndston et al., 1991. A simple, rapid, and reliable method for selecting or assessing the number of replicates for animal experiments. *Journal of Animal Science 69:67-76.* Assumes 90 percent power at $P < 0.05$.

producer cannot do that and use the present feed delivery system. In order to use the feed delivery system in the facility, the producer must provide the control feed to the entire barn for one turn and then the test feed during the following turn. The trial continues in this fashion in order to achieve adequate replication. This approach confuses or confounds the effect of feed type with time, increasing the chance of drawing the wrong conclusion about feed type. The decision as to whether to proceed with such a trial should be based on costs and how much risk the producer is willing to accept for invalid results.

Select the Proper Pens

All pens in the trial must be the same size and have identical equipment (floors, feeders, waterers, etc.). Also, pen location within a building should not be allowed to influence the outcome of the trial; otherwise, one feed type may appear superior simply because the pigs consuming it were in pens that provided a better environment.

Blocking is a good technique to ensure that a comparison between two feeds is as fair and accurate as possible. By blocking, you are making your trial more efficient because you are randomly assigning treatments within known sources of variation. This reduces the amount of replication required in your trial. Adjacent pens, each having a separate feeder, constitute a block of pens. Provide the control and test feed within each block of pens.

An example of the use of blocking in a trial involving sows would be to randomly assign feeds to sows within parities. It is widely recognized that sow reproductive performance varies according to parity. To minimize variation due to parity, block according to parity. That is, have equal numbers of parity 1 and parity 2 sows on each feed type.

To demonstrate use of blocking in a nursery pig feed trial, assume eight pens are available to compare the control and test feeds.

1. Divide adjacent pens into blocks of two pens each (*Figure 2a*).
2. Cut two small pieces of paper and write "C" on one and "T" on another.
3. Fold the pieces of paper, mix, and draw one.

The first slip of paper drawn reveals the feed to be provided in Pen 1 Block A. The feed type not chosen would be provided in Pen 2 Block A. Replace the drawn slip and repeat the procedure until all eight pens have been assigned a feed (*Figure 2b*).

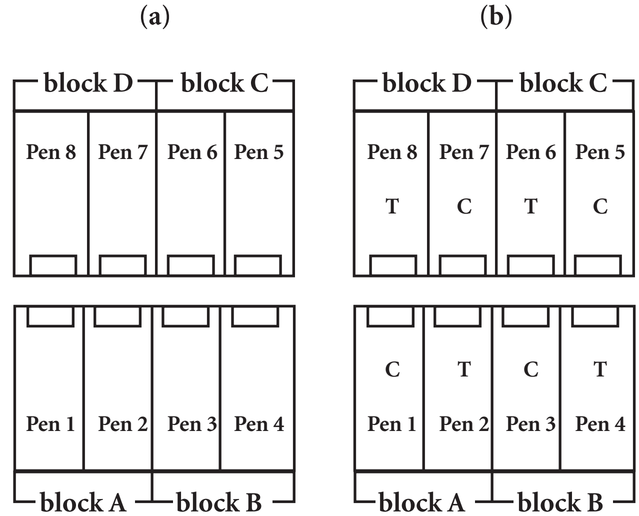

Figure 2. Assignment of control (C) and test (T) feeds to pens.

It is often convenient to use pens along one side or an alley for one feed and pens across the alley for the other feed. This arrangement is valid only after establishing that the pigs perform the same on both sides of the alley. Because it requires extensive research to prove that pigs perform similarly on both sides of an alley, we suggest that the feeds be assigned to blocks of pens as described in the previous section.

Minimize Pig Weight, Ancestry, and Gender Effects

Pigs perform differently because of their weight, ancestry, and gender. These effects must be equalized across all feed types in the trial. Ear notch or tag the pigs to preserve their identity before assigning pigs to pens.

The simplest way to minimize these effects when comparing two feed types is to identify two pigs from the same litter of similar weight and gender. Put one in a pen where the control feed is offered and the other in the pen with the test feed. Choose two additional pigs from the same litter of similar weight and gender and place them in another pair of two pens. Continue choosing pigs from that litter until no more pigs are available. Repeat this process with other litters until pens offering the control and test feeds have the same number of pigs of the same gender ratio and similar live weights.

The number of barrows does not need to be the same as the number of gilts in a given pen; however, the ratio of barrows to gilts and total number of pigs must be the same in each pen. All pigs should be randomly assigned to pens to ensure the integrity of the experiment.

Initial pig weight is considered similar between control and test feed pens when the difference between control and test feed pig weights is less than 2 percent of the average weight of all pigs in the trial. For example, after assigning pigs to pens it is determined the average initial weight of pigs to be fed the control and test feeds is 13.9 lb and 14.1 lb, respectively. The average weight of all pigs in the trial is 14 lb. Thus, the difference in average initial weight between pigs to be fed control and test feeds is less than 2 percent of the average weight of all pigs in the trial (see below).

14.1 lb – 13.9 lb = 0.2 lb
(0.2 lb ÷ 14 lb) x 100 = 1.4%

If the difference between control and test feed pig weight is greater than 2 percent of the average weight of all pigs, then pigs need to be relocated on a random basis to reduce the average initial weight difference between feed types. In addition, it is important to minimize weight variation within pens.

Sometimes it is not possible to eliminate variation due to initial pig weight, gender, or ancestry. Some data analysis programs allow for the use of a covariate, which adjusts the final data for such sources of variation.

After the pigs are assigned to pens by weight and sex, check each pen for common ancestry. If there are three or more pigs from the same litter assigned to a given pen, exchange pigs of similar weight so no more than two pigs from the same litter remain in a given pen.

Select Suitable Test Animals

Sometimes pigs die before the trial is completed. Carefully screening the animals before they are used in the trial will help reduce this problem.

If a pig dies during the trial, data collected from the dead pig's pen must be adjusted. To adjust on-test pen weight, subtract the dead pig's on-test weight from the pen total. Adjust pen feed intake data by determining average daily feed intake per pig for the period the dead pig was alive. Multiply by 0.75 to estimate daily feed intake for the dead pig. Calculate total feed consumed by the dead pig since the onset of the trial and subtract from the total feed consumed by the pigs in the pen. The quantity of feed remaining in the feeder the day the pig died must be determined.

All pigs in a trial should share common backgrounds. For example, they should have received the same feed and vaccinations during the pretrial period. If pigs having dissimilar backgrounds must be used in the trial, for example to obtain a sufficient number of pigs to conduct the trial, be sure the backgrounds of the pigs are balanced across both feed types.

Test Feeds Concurrently

Pigs fed the control and test feeds must begin the trial the same day. Otherwise, you cannot separate the effects of feed type from time. At the end of the trial, weigh the pigs and the feed remaining in all feeders. Be cautious about results from trials comparing before- and after-use closeout data.

Determine Trial Duration

Conduct nursery feed trials for a predetermined time period (three to eight weeks). Growing-finishing feed trials should be terminated when the pigs attain a predetermined weight.

Tabulate Results and Draw Conclusions

Calculate pen averages for each of the response variables in the trial; for example, daily gain, daily feed intake, feed efficiency, feed cost per pound of gain, etc. Then determine the overall average performance for the control and test feed groups (*Table 3*).

People often review data like that in *Table 3* and conclude the test feed is superior to the control. Such conclusions are based on no knowledge of the odds that the differences in performance are actually due to the feed.

Statistics are a tool researchers use to help decide whether observed differences between feed types are due

Table 3. Example average daily gain results from a nursery pig feed trial.

	Feed: Control		*Feed: Test*	
Block	*Pen no.*	*Daily gain, lb*	*Pen no.*	*Daily gain, lb*
A	1	0.79	2	0.83
B	3	0.83	4	0.80
C	5	0.83	6	0.88
D	7	0.79	8	0.86
	Average	0.81	Average	0.84

to real effects of the feed or to random differences due to the sample of pigs assigned to each treatment. For best results, we recommend a statistician be consulted to analyze the data.

A procedure for analyzing data to help make valid conclusions is presented in *Table 4*. The data in *Table 3* is used to demonstrate the procedure. A pocket calculator with a square root function key (√) is required.

Because line 14 is larger than line 13 in *Table 4* (3.182 vs. 1.451), growth rates of 0.81 and 0.84 lb per day are not different. Thus, it is appropriate to conclude that the test feed offers no advantage in terms of daily gain over the control feed in this trial. Although 0.84 is a larger number than 0.81, the chance that they are different because of differences between the feeds is poor. Had line 13 been larger than line 14, it is appropriate to conclude that the test feed is superior to the control feed. The same procedure should be applied to daily feed intake, feed efficiency, and feed cost per pound of gain data before overall conclusions are drawn.

The numerical difference observed in daily gain (0.84 vs. 0.81 lb per day) may be economically important for a pork producer. However, until additional trials are conducted using the same feeds, a producer cannot be 95 percent accurate that switching to the test feed would improve performance.

It is important to remember that trial results may be valid only for a short time. Feed manufacturers change their formulas, thus the feeds tested may be available for a limited time.

The computations used in *Table 4* can be programmed into a spreadsheet. Then a statistical analysis of data can be made conveniently.

Feed trials may prove valuable in choosing a feeding strategy for specific farm conditions. The recommendations presented here will provide producers better information. A blank worksheet for data analysis is provided in *Table 5*.

Table 4. Example of a completed worksheet for statistical evaluation of feed trial data.

Response variable: Daily gain

1. Complete the following table for each block in the trial.

Block	Column 1 Average of pens containing control feed	Column 2 Average of pens containing test feed	Column 3 Difference (column 2 – column 1)	Column 4 Square of values in column 3
A	0.79	0.83	0.04	0.0016
B	0.83	0.80	-0.03	0.0009
C	0.83	0.88	0.05	0.0025
D	0.79	0.86	0.07	0.0049
Total:			0.13	0.0099

2.	Enter number of blocks in the trial.	2.	4
3.	Subtract the number "1" from line 2.	3.	3
4.	Enter the total from column 3.	4.	0.13
5.	Enter the total from column 4.	5.	0.0099
6.	Divide line 4 by line 2.	6.	0.0325

Line 6 is the average difference between control and test feeds.

7.	Calculate the square of line 4.	7.	0.0169
8.	Divide line 7 by line 2.	8.	0.0042
9.	Subtract line 8 from line 5.	9.	0.0057
10.	Divide line 9 by line 3.	10.	0.0019
11.	Divide line 10 by line 2.	11.	0.0005
12.	Enter the square root (√) of line 11.	12.	0.0224

Line 12 is the "standard error of the difference."

12a.	Divide line 10 by 2.	12a.	0.0010
12b.	Enter the square root (√) of line 12a.	12b.	0.0316
12c.	Divide line 12b by the experiment mean: (0.81 + 0.84) ÷ 2.	12c.	0.0383
12d.	Multiply line 12c by 100.	12d.	3.83

Line 12d is the "coefficient of variation" (CV).

13.	Divide line 6 by line 12. *Note: Ignore negative signs when performing calculation for line 13.*	13.	1.451

14. Refer to line 2 and choose the appropriate value from the table below.

14. 3.182

No. blocks (line 2)	Value
2	12.706
3	4.303
4	3.182
5	2.776
6	2.571
7	2.447
8	2.365
9	2.306
10	2.262
11	2.228
12	2.201

15. Check the appropriate box:

☐ Line 13 is larger than line 14. ⇨ Conclusion: Performance of pigs fed control and test feed **is** different.

☑ √ Line 14 is larger than line 13. ⇨ Conclusion: Performance of pigs fed control and test feed **is not** different.

Table 5. Worksheet for statistical evaluation of feed trial data.

Response variable:

1. Complete the following table for each block in the trial.

Block	Column 1 Average of pens containing control feed	Column 2 Average of pens containing test feed	Column 3 Difference (column 2 – column 1)	Column 4 Square of values in column 3
Total:				

2.	Enter number of blocks in the trial.	2.
3.	Subtract the number "1" from line 2.	3.
4.	Enter the total from column 3.	4.
5.	Enter the total from column 4.	5.
6.	Divide line 4 by line 2.	6.

Line 6 is the average difference between control and test feeds.

7.	Calculate the square of line 4.	7.
8.	Divide line 7 by line 2.	8.
9.	Subtract line 8 from line 5.	9.
10.	Divide line 9 by line 3.	10.
11.	Divide line 10 by line 2.	11.
12.	Enter the square root (√) of line 11.	12.

Line 12 is the "standard error of the difference."

12a.	Divide line 10 by 2.	12a.
12b.	Enter the square root (√) of line 12a.	12b.
12c.	Divide line 12b by the experiment mean.	12c.
12d.	Multiply line 12c by 100.	12d.

Line 12d is the "coefficient of variation" (CV).

13. Divide line 6 by line 12. *Note: Ignore negative signs when performing calculation for line 13.* 13. ______

14. Refer to line 2 and choose the appropriate value from the table below. 14. ______

No. blocks (line 2)	Value
2	12.706
3	4.303
4	3.182
5	2.776
6	2.571
7	2.447
8	2.365
9	2.306
10	2.262
11	2.228
12	2.201

15. Check the appropriate box:

☐ Line 13 is larger than line 14. ⇨ Conclusion: Performance of pigs fed control and test feed **is** different.

☐ Line 14 is larger than line 13. ⇨ Conclusion: Performance of pigs fed control and test feed **is not** different.

Checklist for Evaluating Feed Trial Results

Results from farm feed trials are presented in sales meetings and promotional materials often with few details about how the trials were conducted. Before feed trial results are accepted and applied, inquire about some basic principles of good experimental design and procedures. Use this checklist to assist in evaluating feed trial results. "Yes" responses suggest that sound experimental procedures were applied and the trial results are probably valid.

1) Was more than one pen of pigs fed each feed type? (Note: two pens sharing the same feeder constitute one pen.)

   _____yes _____no _____don't know

2) If yes, how many pens per feed type? _________

3) Was the number of pigs per pen, feeder type, flooring space per pig, feeder, and waterer space per pig the same in each pen?

   _____yes _____no _____don't know

4) Were steps taken to reduce the chance that pen location in the room or building influenced the results?

   _____yes _____no _____don't know

5) Was the difference in average initial pig weights between feed types less than 2 percent of the average weight of all pigs in the trial?

   _____yes _____no _____don't know

6) Was the ratio of barrows to gilts the same in each pen?

   _____yes _____no _____don't know

7) Were results from feeding the control and test feed(s) generated at the same time or concurrently?

   _____yes _____no _____don't know

8) What is the standard error of the difference between the feeds evaluated? (Note: If the average difference between feeds (*Table 4*, line 6) is less than two times the standard error of the difference (*Table 4*, line 12), the results being evaluated are probably not reproducible on a given farm.)

Explanation of Some Statistical Notations Used in Research Reports

Feed trial results sometimes are accompanied by certain statistical notations or terms such as $P < 0.05$, standard errors, linear or quadratic, and correlation. What do those mean and how can they be used to help you interpret data?

Statistics are used to calculate the probability that observed differences between treatments were caused by the luck of the draw when pigs were assigned to treatments. The lower this probability, the greater confidence we have that real treatment effects exist. In fact, when this probability is less than 0.05 (denoted for example as $P < 0.05$), there is less than a 5 percent chance (less than 1 in 20) that observed treatment differences were due to chance rather than the feed. The conclusion, then, is that the treatment effects are real and caused different performance for pigs on each treatment. However, bear in mind that if the researcher obtained this result in each of 100 trials, five trials with this difference would be declared to be real when they were really due to chance. Sometimes the probability value calculated from a statistical analysis is $P < 0.01$. Now the probability that chance caused observed treatment differences is less than 1 in 100. Evidence for real treatment differences is very strong.

It is commonplace to say differences are significant when $P < 0.05$, and highly significant when $P < 0.01$; however, P values can range anywhere between 0 and 1. Some researchers say there is a tendency that real treatment differences exist when the value of P is between 0.05 and 0.10. Tendency is used because we are not as confident that differences are real. The chance that random sampling caused the observed differences is between 1 in 10 and 1 in 20.

Sometimes researchers report standard errors of means (SEM) or standard errors (SE). These are calculated from the measure of variability and the number of pigs in the treatment. A treatment mean (or average) may be given as 11 ± 0.8. The 11 is the observed mean and the 0.8 is the SEM. The SEM or SE is added and subtracted from the treatment mean to give a range. If the same treatments were applied to an unlimited number of animals the probability is 0.68 (1 = complete certainty) that their mean would be within one standard error of the observed mean. In the example the range is 10.2 to 11.8.

Some researchers report linear (L) and quadratic (Q) responses to treatments. These effects are tested when the researcher used increasing increments of a factor as treatments. Examples are increasing amounts of dietary lysine or energy, or increasing ages or weights when measurements are made. The L and Q terms describe the shape of a line drawn to describe treatment means. A straight line is linear and a curved line is quadratic. For example, if finishing pigs were fed diets containing 0.6, 0.7, and 0.8 percent lysine gained 1.6, 1.8, and 2.0 lb per day, respectively, we would describe the response to lysine as linear. In contrast, if the daily gains were 1.6, 1.8, and 1.8 lb per day, the response to increasing dietary lysine would be quadratic.

Probabilities for tests of these effects have the same interpretation as described above. Probabilities always measure the chance that random sampling caused the observed response. Therefore, if $P < 0.01$ for the Q effect was found, there is less than a 1 percent chance that random differences between pigs on the treatments caused the observed response. Some reports contain correlations or measures of the linear relationship between traits. The relationship may be positive (both traits tend to get larger or smaller together) or negative (as one trait gets larger, the other gets smaller). A perfect correlation is one (+1 or -1). If there is no relationship, the correlation is zero.