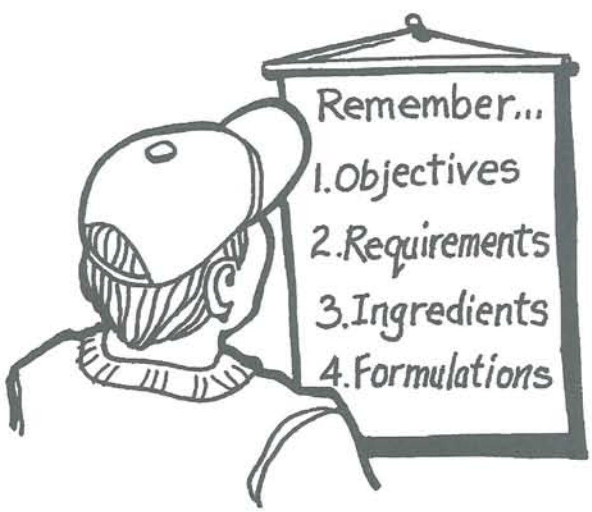
5. DIET FORMULATION

Diet formulation is the process of matching the pig's nutrient requirements with the nutrients supplied by available ingredients, in the most economical manner possible. The process sounds simple enough, but do not be misled. As explained below, nutrient requirements vary among animals and farms. Over-formulation may seem to be a logical way to ensure the animal's requirements are met, but this is costly in both financial and environmental terms. Similarly, defining the nutrients supplied to the pig by various ingredients stills lacks the precision that many of us seek and again, being too conservative in assigning specifications to various ingredients wastes money and nutrients. Finally, linking the process to net income, while essential, requires a firm understanding of the relationship between nutrient supply and animal performance. So, while the process of diet formulation sounds simple enough, it is anything but.

Overall, diet formulation needs to be viewed as a means to an end. The 'end' is efficient production resulting in a final pork product of high quality. Following five basic steps breaks ration formulation down into simpler components that increases the likelihood of success. Diet formulation, and the development of associated feeding programs, is merely one component - albeit an important one - of the overall pork production system.



FIVE STEPS IN SWINE DIET FORMULATION

Define Objectives

Establish Requirements

Select and Characterize Ingredients

Formulate Diets

Evaluate Diets

Define Objectives

The first step in developing a feeding program is to define the objectives; these will include the objectives of the overall business, of the pig unit within the overall business and of individual pigs within the pig unit. Consequently, the nutritionist and the pork producer must communicate to ensure they are both working towards the same objective(s). Following are some typical objectives. It is clear from the following list that "make the most money," as noble (and essential) objective as it may be, is not sufficiently precise!

Maximize Net Income per Pig Place

A pig place is the barn area occupied by a single pig. In a grower barn, a pig place will turn over approximately three times per year; in a nursery, turnover will occur every 5 to 6 weeks, or about 10 times per year. By expressing net income on a 'per pig place' basis, the importance of growth rate, and thus of barn throughput, is recognized. Expressing net income on a 'per pig' basis assigns much less emphasis to barn throughput. Therefore, this objective will be most appropriate where capital costs are high and capital debt exists. If barn throughput increases, fixed costs can be spread over more animals.

In a typical commercial circumstance, the only instances in which one would not want to maximize net income per pig place would be when housing space is not limiting, when market prices do not cover variable costs or when animals are not available to keep the barn full at all times. In the vast majority of circumstances, a farm's profitability will be maximized when farrowing crates, nursery pens and growout facilities are kept filled to their maximum capacity.

Maximize Net Income per Pig Sold

In some instances, such as when housing space is not limiting or when the supply of feeder pigs is limiting, the focus of management will shift from net income per pig place to net income per pig. For example, feeding programs can be designed to move pigs through a barn more quickly. Such diets will tend to be more costly, but if there are no additional pigs to replace those which have moved on to market, the only opportunity to recover the extra feed cost is through reduced inventory costs, such as interest on the operating line of credit.

To Maximize Animal Performance

While most commercial farms will focus on maximizing net income, certain types of farms, notably those involved in genetic selection programs, will seek to maximize animal performance. This ensures that nutrient intake is not confounding selection of animals based on genetic merit. Purebred or nucleus breeding units will typically fall into this category.

Under commercial conditions, producers may choose to feed some animals a 'non-limiting' diet to determine the maximum potential of animals under their particular conditions. For example, the impact of housing, genetics and health can only be determined when nutrient supply is not limiting animal performance.

To Maximize Profits for the Total Farming Unit

In many cases, the pork production unit is associated with other farming enterprises, such as crop production. In this case, the relationship of the pig barn to the other enterprises must be considered. For example, the pig unit may be used to convert certain crops into a more saleable or valuable commodity - pork. In some situations, this could lower profitability of the pig unit, but maximize the net income of the total farm. An example could be the use of lower quality cropping products that lower animal performance but convert a commodity that is unsaleable into one which is more easily sold.

To Minimize the Impact on the Environment

In Canada, as elsewhere, the impact of pork production on the environment is under increasing scrutiny. For example, the spreading of slurry places a nutrient load on the land. While this may be desirable in most cases, due to fertilizing and soil conditioning value, if certain conditions exist, it can lead to a portion of the nutrients entering nearby lakes and rivers due to runoff. Because diet composition affects slurry composition, individual pork producers may manipulate nutrient loading of the soils in a way that is appropriate for their particular circumstances. Of course, following good management practices for slurry handling would be assumed to be the most important first step in all cases.

To Produce a Carcass Possessing Certain Traits

Production systems that link animal production with the packing industry, through either contract or ownership, increases the opportunity to develop pork products possessing certain traits. This might be related to product uniformity, product quality or possibly even more specific traits such as fatty acid profile or "organic" designation. In some of these instances, diet plays a central roll in achieving the desired final product.

To Establish a Production System that Emphasizes Animal Well-being

Animal well-being is difficult to define, let alone measure, but it is a subject that is attracting greater interest both within and outside the pork industry. Animal well-being is not necessarily impaired by maximizing net income; indeed, profitability and welfare should not be considered as mutually exclusive. Nutrition is rarely associated with violations of animal well-being, other than cases of outright neglect leading to malnutrition and/or starvation. However, this may change as we learn more about basic animal behaviour. Scientists and producers continue to work on providing the pig with the most positive environment while still maintaining a satisfactory profit margin.

From this list, it is clear that the nutritionist's focus will vary among farms. Depending on the circumstances, it may be the carcass, the pig, the barn, the total agri-business of which pork production is only one part, or the environment. In actual practice, nutritionists will consider all of these objectives and vary the emphasis depending on the individual client and his or her particular situation.

Define Requirements

Once the nutritional objectives have been set, the next step is to define the nutrient intake required to achieve them. Nutrients required by the pig depend on many factors that are internal (i.e. genotype, age, sex, expected level of productivity) or external (i.e. thermal and social environment, economic conditions) to the pig. Consequently, these must be considered in establishing the nutrients required in a given diet.

In addition, total daily feed intake must be considered because, in fact, nutrients are required on a daily intake basis. This applies to both the breeding herd and market hogs. Unfortunately, there is a poor understanding of feed intake. Efforts to predict intake are limited in scope and few operations measure it directly. Consequently, while we recognize that nutrient requirements should be expressed on a daily intake basis, in practice they are presented on the basis of dietary concentration. Intake will be discussed in more detail under chapters dealing with the feeding of specific classes of swine.

Nutrient requirements can be established using two approaches. The more traditional system is the empirical method which employs experiments to measure the pig's response to diets of differing nutrient supply. This method has the advantage of employing actual animal response in the evaluation, but often fails to explain why the response was observed. This makes it difficult to extrapolate the results to production circumstances which may differ among farms, due to genetics, environment, or management.

The second approach, the factorial method, attempts to identify the various functions within the animal that require a given nutrient and define the needs based on each. For example, energy is used for maintenance, growth, pregnancy, and lactation. By expressing the requirement for energy on the basis of its use for each process, and incorporating some relationship between requirement and rate of production, one can estimate the pig's requirement for energy for various levels of performance. By adding factors that address energy needs for external forces, such as temperature and level of activity, energy requirements can be predicted - theoretically. The accuracy of such predictions, of course, depends on the precision of the various prediction equations.

Typically, nutritionists use both approaches, with the factorial method increasing in popularity due to the need to define requirements under diverse conditions. However, even where the factorial method is predominant, animal experiments will still be employed to confirm the accuracy of the prediction equations.

Nutrient requirements that are published, for example, by the National Research Council (NRC) or the Agriculture Research Council, are by and large those required to maximize performance. Clearly, if performance somewhat below maximum is the most economical, then the nutrient levels needed may also be somewhat less than those published. Given the information available, one can develop at least a rough estimate of the requirements needed for a given circumstance.

The graph in Figure 5-1 illustrates the general approach to defining the pig's requirement for a nutrient. It shows that as the amount of nutrient being tested is increased in the diet, the pig responds in some way, such as by growing faster, or more efficiently, or by producing bigger litters. When the diet is very deficient, small additions of the limiting nutrient give a large improvement in performance. However, as the requirement is approached, the response of the pig to each unit of nutrient becomes less. This is sometimes called the law of diminishing returns. It is clear from this figure that the greatest return per dollar spent does not occur near the peak of the curve. Depending on the marketplace, it may or may not be economical to provide full supplementation. Again, the factorial approach to defining nutrient requirements is the most adaptable to such changes in expected levels of productivity.

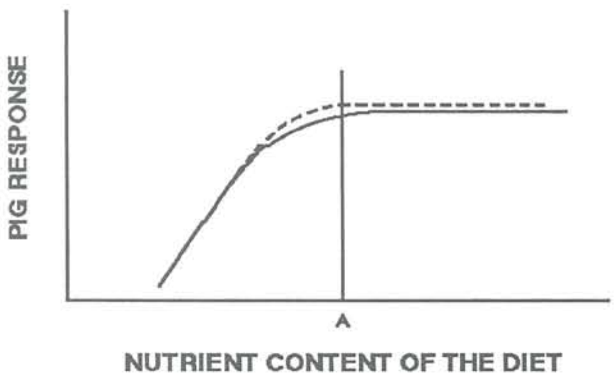


Figure 5-1. Determination of a Nutrient Requirement, Showing the Pig Response to Increasing Nutrient Supply.

For example, when feed is inexpensive and hog markets are strong, feeding the highest quality diet may be the most economical for most farmers. However, in the opposite situation, when feed is expensive and markets are weak, a less ambitious diet would likely be more profitable. It becomes readily apparent that feeding regimes should not be constant from year to year, or even from farm to farm. They need to acknowledge the specific economic circumstances and respond in an appropriate manner. Simply stated, there is no feeding regime that is best under all circumstances.

The process can be complicated by mitigating circumstances, such as the genetic quality of the animals, the management style of the farmer, the financial status of the farm, the environmental conditions in the barn, and so on. The more we learn about the science of nutrition, the better we will be able to tailor diets to the specific needs of individual farmers. This is one aspect of swine nutrition which has advanced the most in the past 5 years, and further progress is expected. "Situation dependent feed formulation" the process whereby feeding programs are optimized for each production system is a major objective if one wants profits to be maximized and the industry as a whole positioned to compete most effectively in the marketplace for the consumers' dollar.

Select and Characterize Ingredients

Once the objectives of the feeding program have been established, and the nutrient requirements defined, the next step is to select the ingredients available and determine their nutrient content.

Selecting ingredients is not a difficult task, as they are usually the ingredients at hand. However, advantages may be gained by seeking out less common ingredients that represent good value and can be successfully integrated into a swine feeding program. A review of ingredients in Chapter 4 may be helpful in this regard.

Determining the nutrients supplied by the ingredients is much more difficult, involving essentially two steps: determining the nutrient composition of the ingredient and determining the availability to the pig of those nutrients. While a more thorough discussion of this subject appears in Chapter 3, a few of the more pertinent points will be summarized below.

The best method of determining nutrient composition is chemical analysis. The most important analyses required on cereal grains and protein meals (canola meal, soybean meal) are crude protein, calcium and phosphorus. If moisture problems are suspected, dry matter analysis should also be requested. While chemical assays are relatively easy and inexpensive for common nutrients, they are more expensive and time consuming for nutrients like amino acids and vitamins. Therefore, in the interest of time and economics, amino acid levels are estimated from protein content (see chapter 3) or book values are employed, if available. For the most part, these approaches are adequate. However, if book values are used, the variability of the ingredient must be acknowledged, as individual samples rarely reflect the average.

Crude protein is an indirect measure of protein, based on the amount of nitrogen in a feedstuff. Since most of this nitrogen is present as protein, this information is used to estimate actual protein. On average, most proteins in grain and vegetable protein sources contain about 16 percent nitrogen. Thus, if one knows the nitrogen content, multiplying this value by 6.25 ($100 \div 16 = 6.25$) will estimate protein (refer to pages 71-74 for more detail).

Once total nutrient content is established, then the availability of those nutrients to the pig must be considered. This approach is universally applied in the case of energy, where digestible or metabolisable energy are always used in place of gross energy; however, for amino acids and minerals, availability is considered less often, a situation which we believe to be most unfortunate. Availability cannot be determined directly on individual samples without using animal tests. Since this is expensive and far too time consuming, indirect methods, such as Near Infrared Spectroscopy (NIR), where available, or book values, must be employed.

There are other considerations as well. First, it must be remembered that the grading system for grain was designed to satisfy the needs of an export market and for the milling industry, rather than to meet the needs of those in the livestock industry. Thus, many of the factors that cause downgrading of grains are of little or no consequence to animal nutritionists.

A case in point is bushel weight. Although very low bushel weight may be reflected in lower energy content, a wide range is perfectly acceptable to the pig. Table 3-5 outlines minimum acceptable bushel weights for swine diets. Values below the minimum are still acceptable, but some lowering of estimated energy content would be advised. Refer to chapter 3 for details.

Visual appraisal, although subjective, should not be underestimated. Freedom from weed seeds, especially those that are unpalatable or toxic, is obviously very important. Sprouting, mold or contamination are other things to watch for.

Diet Formulation

Once the nutritional objectives have been established, the requirements identified and the ingredients selected and characterized, the next step is to put this information together into a formula that can be used to make the diet. This can be done using any one of at least three methods:

1. Linear programs (computer formulation)
2. Algebraic formulas
3. Pierson's Square

1. Linear programs

The speed and simplicity of computer formulation of diets makes it the most effective and popular method for anyone involved in the process on a regular basis. Rather than use the more simplistic and slower algebraic methods or Pierson's Square, the computer can handle many simultaneous equations in a fraction of a second. Because of this speed and simplicity, the computer allows nutritionists to consider more ingredients and more nutrients, and pay far greater attention to cost than would otherwise be the case. However, it is important to remember that the information generated by a computer can be no better than the information provided to it initially!

Essentially, the computer takes the nutrients needed by the pig on the one hand, and the nutrients supplied by available feedstuffs on the other, and combines them to develop a balanced ration at the least possible cost. Computer ration formulation programs use a linear equation (thus, linear programming) such as:

Requirement = aX1 + bX2 + cX3 + dX4

where a, b, c and d are the amounts of each of four ingredients in the diet and X1, X2, X3 and X4 represent the amount of the nutrient in question present in each of the four ingredients.

Recently, feed formulation programs have become much less expensive for producers to purchase. These programs are much smaller than those used by major feed companies, but they will permit simultaneous formulation of a diet considering 50 or more nutrients supplied by 50 or more ingredients. This is clearly more than the average pork producer requires!

There is some question whether the individual pork producer really needs such capability. Is it worth the money to purchase such programs? The answer lies not in the cost of the program, but rather in the time and expertise required to operate it. Errors related to ingredient composition or nutrient requirements can lead to disastrous results. For the most part, diet formulation should be left to professionals with the training and experience required to develop a feeding program that best meets the producer's needs. Ongoing least cost formulation of diets to ensure that feed costs are truly minimized can be carried out on the farm with little risk, provided a nutritionist has been involved in defining the restrictions included in the formulation program.

Table 5-1. Typical Ingredient Output From A Feed Formulation Program.

Ingredients	Formula			Price		
	Actual	Minimum	Maximum	Low	Actual	High
Barley	34.35	-	-	1.13	1.30	1.60
Wheat	36.10	-	40.0	1.43	1.70	1.95
SBM (47%)	11.80	-	-	2.52	2.85	3.36
Canola Meal	15.00	-	15.0	-	1.80	2.00
Dicalcium phosphate	0.69	-	-	-	4.30	77.69
Limestone	1.13	-	-	-	0.61	12.15
Salt	0.33	-	-	-	0.55	-
Mineral Premix	0.30	0.30	-	-	5.20	-
Vitamin Premix	0.30	0.30	-	-	15.00	-
Total	100.00				176.55	

Tables 5-1 and 5-2 outline the type of information provided by a computer-based feed formulation program. In Table 5-1, the ingredient summary itemizes the ingredients selected and the amount required in the diet. Limits (maximums and minimums) that were set up in the original feed specifications are also shown. It can be seen in the example that canola meal was priced competitively, because it went to its upper limit. The premixes are obviously expensive, because they are at their lower limits. The output often also tells the formulator how competitive the price for each ingredient is. For example, soybean meal would have to drop to $252 per tonne in order for more soybean meal to come into the formula. Likewise, if the price rose to $336, the computer would select less soybean meal. There is no lower price limit for canola meal, since it is already using the maximum amount. Wheat appears to be competitively priced, since it is very close to its lower price limit and much cheaper than its upper price. Thus, programs of this nature can be used to determine the value of certain ingredients in various diets used on the farm.

Table 5-2 provides a somewhat similar summary for nutrients (as opposed to ingredients). Nutrients that are at their lower limit are forcing the cost of the diet up. For example, digestible energy, lysine, sodium, calcium and phosphorus are all at their lower limit, meaning that if any of these could be lowered, the cost of the diet would be reduced. However, since animal performance might suffer, reducing the diet cost would not necessarily save money in the long run.

Table 5-2. Typical Nutrient Output from a Feed Formulation Program.

Nutrient	Requirements			Constraint		
	Actual	Minimum	Maximum	Unit Cost	Increment	Decrement
Digestible energy	3200	3200	--	0.001	111.753	117.608
Protein	19.93	--	--	--	--	--
Lysine	0.95	0.95	0.96	--	5.302	2.908
Methionine	0.34	0.29	--	--	--	--
T.S.A.A.	0.74	0.57	--	--	--	--
Tryptophan	0.24	0.18	--	--	--	--
Threonine	0.73	0.59	--	--	--	--
Isoleucine	0.81	--	--	--	--	--
Sodium	0.15	0.15	0.25	0.008	12.914	0.825
Chloride	0.27	0.15	--	--	--	--
Calcium	0.75	0.75	0.80	0.008	12.430	4.248
Phosphorus	0.60	0.60	0.70	0.026	5.099	1.455
Available phosphorus	0.36	--	--	--	--	--

2. Algebraic Formulas

In the absence of computers, sometimes simple calculations are required to balance a simple ration involving only a few ingredients. In such cases, algebraic methods are often selected because they are more accommodating. However, for those not comfortable with algebra, they may be a bit confusing at first. Following is an example:

EXAMPLE

Problem: Formulate a diet to contain 0.78 percent available lysine using five ingredients: barley, wheat, soybean meal, canola meal and premix. Canola meal is assumed to contain 1.45 percent available (ileal) lysine and is fixed at 10 percent of the diet, the premix, containing no lysine, is fixed at 3.5 percent of the diet and wheat, with 0.31% available lysine, is set at 25 percent of the total diet. The barley contains 0.29 percent available lysine and the soybean meal 2.7 percent available lysine.

So far, the diet looks like this:

Barley	?
Wheat	25.0
Soybean meal	?
Canola meal	10.0
Premix	3.5
TOTAL	100.0

Solution:

i) With the wheat and canola meal fixed, this diet already contains 0.22 percentage (.25 * 0.31 + .10 * 1.45 = 0.22) points of available lysine. Thus, the barley and the soybean meal must provide 0.56% available lysine and do so in 61.5 percent of the total mix (100 minus 25.0 minus 10.0 minus 3.5 = 61.5).

ii) Let "X" equal the proportion of barley in the diet and let "61.5 - X" equal the portion of soybean meal in the diet. The amount of available lysine required will be 0.56 percent (0.78 minus 0.22).

iii) The amount of available lysine supplied by barley will be .0029X (X is the amount of barley and .0029 is the portion of barley that is lysine - that is 0.29%) and the amount of available lysine supplied by soybean meal will be .027(61.5-X). That is, the amount of available lysine in soybean meal times the amount of soybean meal in the diet.

Thus, the algebraic equation to solve the problem will be:

$$.0029X + .027(61.5-X) = 0.56$$

The equation will solve as follows:

$$.0029X + 1.6605 - 0.027X = 0.56$$
$$-.0241X = -1.1005$$
$$X = 45.7$$

Therefore, the amount of barley in the diet will be 45.7 percent and soybean meal will make up 15.8 (i.e. 61.5 - 45.7) percent. The final formula will thus look as follows:

Barley	45.7
Wheat	25.0
Soybean meal	15.8
Canola meal	10.0
Premix	3.5
TOTAL	100.0

The algebraic method is adaptable to many kinds of calculations. However, for many of us, algebra is a long forgotten subject; for this reason, the algebraic method is not very popular.

3. Pierson's Square

Pierson's square is an established method that is popular due to its simplicity. However, its simplicity is also its weakness; it functions well only in very simple diets. It is best used in diets containing only two ingredients. For more complex situations, other methods are preferable.

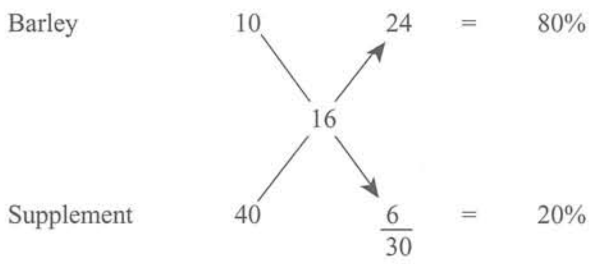
EXAMPLE 1

Problem: Formulate a diet containing 16% crude protein, 0.90% calcium and 0.75% phosphorus, using barley and a 40% hog supplement.

Solution:

i) The barley was analysed, and found to contain 10% crude protein, 0.05% calcium and 0.29% phosphorus. The hog supplement, according to the label, contains 40% crude protein, 4.3% calcium and 2.6% phosphorus.

ii) Determine the proportion of barley and supplement needed to provide 16% crude protein in the final mix, using Pierson's Square.



Pierson's Square is used as follows. Place the percent protein adjacent to the ingredient and the desired level in the centre of the square. Subtract in the direction of the arrows (i.e. 16 - 10 = 6 and 40 - 16 = 24). Sum these two values to get 30 (i.e. 24 + 6 = 30). Divide 24 by 30 to get the percentage barley in the diet and 6 by 30 to get the same information for the supplement.

This method can, in fact, be used for any nutrient, not just crude protein.

iii) Now that the proportion of barley and supplement needed to meet the crude protein requirement have been determined, the next step is to balance for calcium and phosphorus. This can be accomplished by completing Table 5-3.

Table 5-3. Diet Composition from Pierson Square Calculation.

Item	Barley	Supp.	Diet
Percent in diet	80	20	100
<u>Composition, %</u>			
calcium	0.05	4.3	-
phosphorus	0.29	2.6	-
<u>Supplied to diet, %</u>			
calcium	0.04	0.86	0.90
phosphorus	0.23	0.52	0.75

The calculations go as follows:
Barley represents 80% of the mix and contains 0.05% calcium, while the supplement represents 20% of the mix and contains 4.3% calcium. The total calcium in the diet will therefore be 80 percent of 0.05 + 20 percent of 4.3 (.80 x 0.05 + .20 x 4.3 = 0.04 + 0.86 = 0.90). A similar calculation can be made for phosphorus.

Fortunately, the diet works out, such that the calcium and phosphorus supplied by the supplement and the barley provides exactly the amounts required in the final mix. This may not always be the case. However, one cannot formulate the diet solely on the basis of protein and select the amount of supplement so dictated. The feed manufacturer assumed a certain rate of use when the supplement was formulated. This add rate will therefore supply the amino acids, vitamins and minerals required. However, if less or more of the supplement is used, errors in other nutrient levels may result. Thus, the manufacturer's recommendations for inclusion should be followed within 2-3%; if this is not acceptable, a special supplement may be required.

The Pierson square method can be used for somewhat more complicated formulations, as shown by example 2, a diet with three ingredients: barley, soybean meal and premix.

<u>EXAMPLE 2</u>

<u>Problem</u>: Formulate a diet containing 16 percent protein, 0.90 percent calcium and 0.75 percent phosphorus using three ingredients: barley, soybean meal and premix.

<u>Solution</u>:
i) The barley has the same analysis as that used above, the soybean meal was analysed and found to contain 46.5% crude protein, 0.25 percent calcium and 0.61 percent phosphorus and the premix, according to the label contains no protein, 26 percent calcium and 14 percent phosphorus.

ii) Set up the Pierson's Square as shown. Since the premix is added according to the label at the rate of 3 percent of the total mix, then the barley and soybean meal must be proportioned to supply 16% crude protein in the total mix, which in effect is diluted 3 percent by the premix. Thus, the percent crude protein in the barley:soybean meal mix must be adjusted upwards by 3 percent. Thus, the 16 percent value in the centre is adjusted to 16.5 (16.0/0.97 = 16.5).

Barley	10	30	82.2%
	16.5		
Soybean meal	46.5	6.5	17.8%
		36.5	

The proportions for each ingredient relate to the 97% of the diet that will be barley and soybean meal. They must be adjusted to fit the final diet as follows:

Barley 82.2 x 0.97 = 79.7%
Soybean meal 17.8 x 0.97 = 17.3%

Calculating as above, the formula for the diet will be:

Barley	79.7
Soybean meal	17.3
Premix	3.0
	100.0

The calcium content of this diet will be (.797 x 0.05 + .173 x 0.30 + 0.03 x 26.0) = 0.83 % and the phosphorus content (.797 x 0.29 + .173 x 0.61 + 0.03 x 14.0) = 0.76%. These are both close enough to the expected values.

This approach can be extended, for example, to situations where both wheat and barley are being used, by using a composite protein content for the grains in place of the barley value used above. In the case of a 50:50 mix of wheat and barley, containing 13.5% and 10% protein, respectively, a value of 11.75% would be used in place of the 10% value for barley in the above examples.

Evaluating Diet Quality

Once diets have been manufactured, there is only one way to know if the diet was mixed correctly. A feed sample must be submitted for chemical analysis (crude protein, calcium, phosphorus, salt). The results of the analysis can be compared to the expected values. If they are within a tolerance range of approximately 5-7% for crude protein (eg: a 16% protein diet should fall within the ranges of 15.2 to 16.8%) and 10-15% for minerals such as calcium, phosphorus and salt, one can be assured of a job well done. If the results are outside this range however, there is a problem and the cause must be determined. It may have occurred at any of the three steps in the process: sampling, mixing and/or formulation. It is also possible that an error could have occurred in the laboratory. For this reason, samples sent to the lab should be split and a duplicate sample retained for later reference. Some producers will send duplicate samples to two laboratories, particularly if a definite answer is required and lab error needs to be eliminated. However, if well-run laboratories are used, lab errors should be minimal.

Quality control, that is the actual chemical analysis of mixed diets, is required to ensure the adequacy of all diets fed to pigs.

Collecting samples of diets or ingredients must be done correctly if the analytical results are going to truly reflect the actual composition. Grain should be sampled from a bin using a grain probe, selecting no less than 20 subsamples from different locations that can be mixed together and submitted as a single representative sample. If a probe is not available, at least 20 grab samples should be obtained from different locations. Care must be taken in sampling below the surface of the standing sample.

For diets, a minimum of 20 subsamples should be collected from the holding bin or from at least 6 different feeders in the barn. These should be thoroughly mixed together into a single composite sample before sending to the lab.

Mixed feed can be sampled from a number of feeders in the barn or as the feed is mixed. The key is to get a truly representative sample of the material. Note that if feed is collected from the feeders, poor analytical results may be caused by separation during handling and delivery, rather than by mixing or formulation errors. These samples should be thoroughly mixed before submitting them to the lab to ensure a good representative mix. If separation is being investigated, then they should not be mixed, but sent as individual samples to the lab.

Producers should check the calibration of their mill to ensure that no errors have been made and also the formulas for their diets to ensure that they are correct. Table 5-5 illustrates how to determine the quantity of a nutrient in a diet. The mix size is first corrected to 100. The nutrients supplied by each ingredient can then be easily calculated by multiplying the concentration of nutrient in each ingredient by the amount of ingredient in the feed. The amounts supplied by each ingredient are added together to get the total quantity of nutrient in the feed.

Table 5-4. Recommended Schedule for Feed Testing on a Farm Manufacturing Three Diets.

Month	Sample				
	Ingredients		Feeds		
	Home Grown	Purchased	Starter	Grower	Sow
Jan	--	C	C	C	A
Feb	--	C	C	A	C
Mar	C	A	A	C	C
Apr	--	C	C	C	A
May	--	C	C	A	C
Jun	C	A	A	C	C
Jul	--	C	C	C	A
Aug	--	C	C	A	C
Sep	A (new crop)	A	A	C	C
Oct	--	C	C	C	A
Nov	--	C	C	A	C
Dec	C	A	A	C	C

C: Collect and retain sample; analyse only if problems are suspected. If there are no problems, retain sample in a cool, dry, dark location for one year and then discard. In this way, if a problem occurs later, these samples will be available for use.

A: Collect and analyse. In addition to this, twice a year samples should be selected from three or four different feeders in each of the three to four sections of the barn. Analyse each sample to determine if separation is occurring.

Table 5-4 provides a recommended schedule for feed sampling and testing on a farm where three diets are being manufactured. The schedule assumes that no problems are detected. If there is a problem, more intensive testing will be needed until the problem is resolved.

The diet in Table 5-5 is well-balanced with respect to lysine, calcium and phosphorus. Assuming that unusual ingredients are not used and that the premix is correctly formulated, if these three nutrients (lysine, calcium, phosphorus) are correct, the rest of the diet will likely be acceptable. It would not be necessary to check each and every nutrient in the diet.

If problems in the feed analysis are discovered, it is important to check other sources of error such as sampling or analysis **before** adjusting the mill. If mill calibration is the problem recalculate the diet and adjust the mill according to the revised formula. It is imperative that the mill is not adjusted by 'one or two clicks' to compensate for excess protein. If this practice is common, it will not be long before the mill is totally out of calibration and serious errors will result.

In summary, if one obtains poor results from an analysis, then the lab, the formula, the mill, the delivery system and the method of sampling can all be potential sources of error and should be re-checked. A flow chart summarizing the above procedures appears in Figure 5-2.

Table 5-5. Calculation of the Theoretical Nutrient Composition of a Feed.

Ingredient		Lysine		Calcium		Phosphorus	
		Ingredient	Diet	Ingredient	Diet	Ingredient	Diet
Barley	44.3	0.39	0.173	0.07	0.031	0.29	0.128
Wheat	40.0	0.39	0.156	0.04	0.016	0.34	0.136
Soybean meal	11.0	3.15	0.347	0.26	0.029	0.60	0.066
Canola meal	1.7	2.02	0.034	0.65	0.011	1.07	0.018
L-lysine HCI	0.2	78.40	0.157	-	-	-	-
Premix	3.0	-	-	26.00	0.780	14.00	0.420
TOTAL	100.0		0.866		0.867		0.769

The diet contains the proportions of ingredients shown expressed as parts per 100. Example: the lysine supplied by barley will be 0.443 x 0.39 = 0.173.

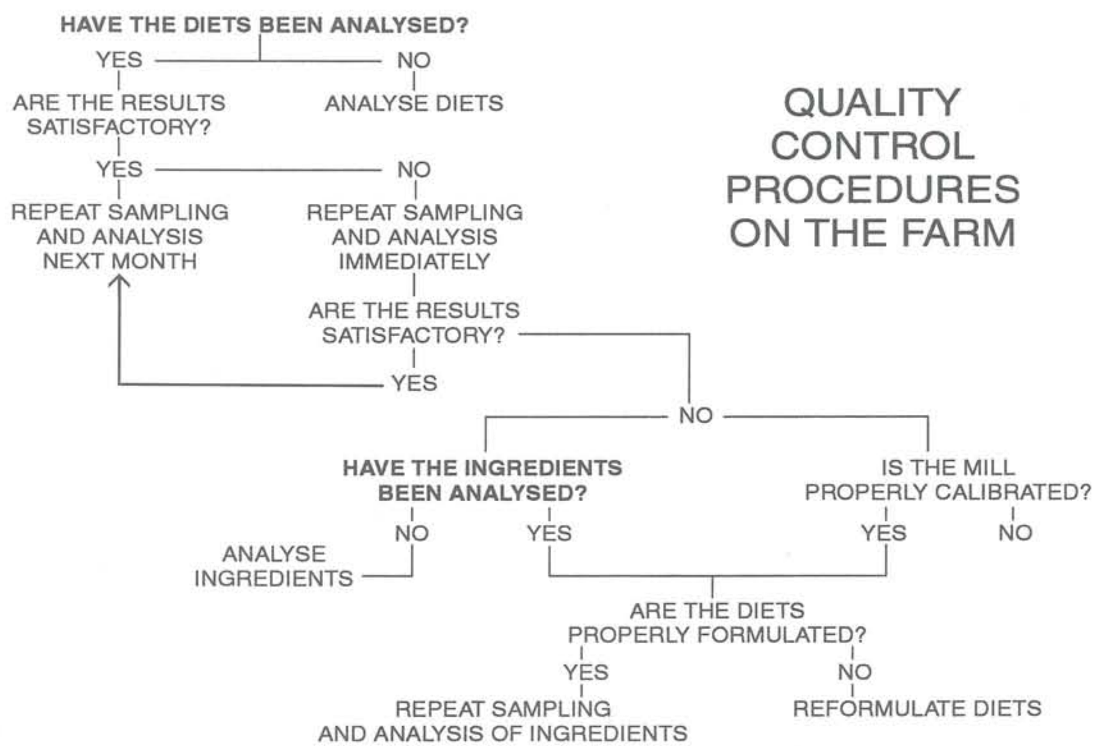


Figure 5-2.

Conducting a Feeding Trial

Producers often need to compare two or more feeds in terms of performance and profitability. The best way to compare feeds is to conduct a feeding trial in which the growth rate and feed efficiency of the pigs on various diets can be compared. The trial must be carried out properly if the results are to be meaningful. The comparison cannot have biases that might favour one diet over another. Provided these precautions are taken, one can be reasonably assured that the differences observed are due to the diets used in the test and not due to an outside influence. The following are guidelines that will help ensure an effective comparison:

1. Split litters among the various diets being tested. The effect of litter and genetics can be very large, especially in starter trials.

2. Use more than one pen per diet even through it increases the workload. If only one pen is used, the results in favour of one diet or another could very likely be due to chance. For a test to be effective, at least three to four pens per diet are required.

3. Spread the pens on each diet throughout the barn or room. This reduces biases due to pen location. In almost all barns, there are pens that support better performance than others.

4. Treat all pigs on the diets **equally**. Factors such as feeder type, number of pigs per pen, pen size and shape, pen flooring material, waterer numbers, type and location can all have an affect on performance. Therefore, the impact of such factors cannot be allowed to bias the results of your experiment.

5. Be sure to compare diets at the same time. Running one diet at one point in time and the second diet at a later date could result in differences in performance related to season or variable barn environment.

6. The average initial weight should be the same for all treatments. Heavier pigs will obviously grow faster but convert feed less efficiently than smaller pigs.

7. Sex is another important factor. In starter trials, sex can be ignored because there is little difference between barrows and gilts at this age. As they grow older though, differences in growth rate and carcass quality emerge.

If the comparison keeps these points in mind, any differences observed in performance will likely be due to diet. Random variation in the performance of pigs does occur. Therefore, consistent differences between diets are needed to draw meaningful conclusions. For example, if pigs on diet A grew an average of 10% faster than pigs on diet B, but three out of six individual pens grew fastest on diet A and three grew fastest on diet B, the overall 10% difference in meaningless and no apparent difference in the diets exists. If there was an overall difference of 10% though, and five out of the six individual pens grew faster on diet A, then one can be reasonably certain that it is a better diet (Table 5-6).

Ensure diets contain the same medication, especially when studying starter diets. Performance can be greatly influenced by medication as well as by make-up of the diet. To compare only the diets, differences due to medication should be eliminated. Again, the key to running a proper test is to eliminate or at least minimize all sources of variability other than the factor being evaluated.

Select the pens and the pigs for the feeding trial. Randomly assign pigs to the test pens assuring that the average initial weight is constant and that litters are spread out among pens. If the experiment ends before the pigs reach 25 kg, do not separate them by sex. If older pigs are being used, sex differences start to show up and the number of barrows and gilts in each pen should be the same. Record the total weight of pigs within each pen and randomly allot diets to the test pens. Add a known amount of feed to each feeder. As the experiment progresses, continue to add feed as required, keeping records of how much feed was added to each pen. At the end of the experiment, weigh all of the pigs and record the amount of feed left in each feeder. The following calculations should be made to help draw conclusions:

1. final weight of pigs - starting weight of the pigs = total pig gain

2. total pig gain ÷ number of pigs = total gain per pig

3. total gain per pig ÷ number of days on test = average daily gain

4. total feed added to feeder - feed left at end of trial = total feed consumed

5. total feed consumed ÷ number of pigs = feed consumed per pig

6. feed consumed per pig ÷ number of days on test = average daily feed

7. total feed consumed ÷ total gain = feed conversion

8. feed cost per tonne ÷ 1000 = feed cost per kilogram

9. feed conversion x feed cost per kilogram = feed cost per kilogram gain

Table 5-6. Examples of Conclusive (Experiment 1) and Inconclusive (Experiment 2) Test Results, Based on Average Daily Gain (g/pig/day).

Group	Experiment 1		Experiment 2	
	Diet A	Diet B	Diet A	Diet B
1	441	400	441	100
2	394	380	394	410
3	410	375	410	220
4	411	400	451	401
5	438	401	390	380
6	430	380	440	523
Average	421	389	421	389

Although the average performance on each diet is the same in both experiments, Experiment 2 would not support the conclusion that Diet A is better. Note that in Experiment 2, Diet A outperformed Diet B only four out of six times. In Experiment 1, Diet A outperformed Diet B six out of six times.

If differences are small or results are in any way questionable, repeat the experiment to strengthen and provide confidence in the results. In **all** cases, remember that bad information is worse than no information at all. If the time, money and trouble is to be invested in an on-farm test, efforts should be made to carry it out properly.

Common Calculations and Conversions

Converting 'dry matter' values to 'as fed':

Multiply the dry matter value by percent moisture.

Example 1: Convert dry matter to 'as fed'. A sample of barley has 11.2% crude protein (CP) on a dry matter (DM) basis and contains 10.5% moisture. Express the percent protein on an as fed basis.

Solution:
If the barley contains 10.5% moisture, it contains 89.5% (100-10.5 = 89.5%) dry matter. The amount of protein on an as fed basis then, is 10.0% (11.2 x 0.895 = 10.0%).

Example 2: Convert 'as fed' to 'dry matter'. A sample of barley has 11.0% protein on an as fed basis and contains 10.0% moisture. Express the percent protein on a dry matter basis.

Solution:
If the barley contains 10.0% moisture, it contains 90.0% (100-10.5 = 90.0%) dry matter. The amount of protein on a dry matter basis then is 12.2% (11.0 ÷ 0.90 = 12.2%).

Additional Reading and References

Agricultural Research Council. 1981. The Nutrient Requirements of Pigs. Commonwealth Agricultural Bureaux, Farnham Royal. 307 pp.

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National Research Council. 1988. Nutrient Requirements of Swine, 9th Ed. National Academy Press, Washington. 93 pp.