One reason for higher protein levels in feed than required is that swine feeds typically only contain two major amino acid sources (corn and soybean meal). Because the objective of feed formulation is to match the content of at least five amino acids in those feed ingredients with the animal's requirement, only using two feed ingredients does not provide much flexibility… .

Precision Nutrition

As indicated above, pigs require nutrients in precise ratios for maximum growth and for maximum efficiency of growth. A good analogy to this is putting a square peg in a round hole. Unless the square peg is smaller than the hole, it does not fit. If the peg is too large, it is necessary to cut away precious wood (nutrients) to make it fit, while a peg that is too small is wasteful because it does not provide optimal fit (maximum growth). **Thus, for optimum efficiency of nutrient use, it is important to feed pigs the right quantity of nutrients in an ideal ratio.**

Pigs are often overfed as a measure of security or simply because that diet is the cheapest to manufacture. Feed formulation packages typically determine which diets meet the nutritional requirement of the animals at a minimum dietary cost. Such diets, however, are not necessarily optimized from an economic point of view (as they ignore the law of diminishing returns and only take diet cost in consideration), and they are definitely not optimized from an environmental point of view. Especially in cases where disposal of nutrients is costly, having a slightly less rich diet leading to suboptimal performance but with greatly reduced nutrient excretion may actually be economically attractive.

The result of current least-cost diet formulation software is, according to Lenis and Schutte (1990), that the protein content of a typical swine ration could be reduced three percentage points (e.g., from 16% to 13%; achieved by replacing, e.g., soybean meal with synthetic amino acids and corn) without negative effects on animal performance. Such a reduction could exert a large impact on N excretion in manure. Schutte et al. (1993) determined that for each percentage point that N is reduced in the feed, N excretion is reduced by 10%. Monge et al. (1998) confirmed this observation, claiming an 11% reduction in N excretion for each percentage point reduction in protein in the feed. When reducing N excretion through precision nutrition, ammonia emission is reduced in similar proportions.

One reason for higher protein levels in feed than required is that swine feeds typically only contain two major amino acid sources (corn and soybean meal). Because the objective of feed formulation is to match the content of at least five amino acids in those feed ingredients with the animal's requirement, only using two feed ingredients does not provide much flexibility, automatically leading to large excesses for some of the amino acids (Figure 10-2). By using more ingredients (that are cost competitive), the protein content of the diet can typically be reduced without sacrificing performance. A simple example is to replace some of the soybean meal in a C-SBM diet with synthetic lysine, which contains 78% digestible lysine. For the test diets examined (Figure 10-3 and Table 10-4), this would reduce the protein in the diet by approximately 1.5 percentage points. Making tryptophan, threonine, and methionine available at competitive prices could reduce the protein content of the diet even further. Synthetic ingredients provide an obvious example of the benefit of multiple ingredients, but ingredients such as meat and bone meal, wheat, or barley provide similar benefits.

Hobbs et al. (1996) extended the potential benefits of the precision nutrition concept by evaluating the effect of low-protein diets on the concentration of odorous compounds in manure. Their work clearly demonstrates that minimizing a diet's protein content not only substantially reduces N excretion in the manure but also reduces odor compounds in the

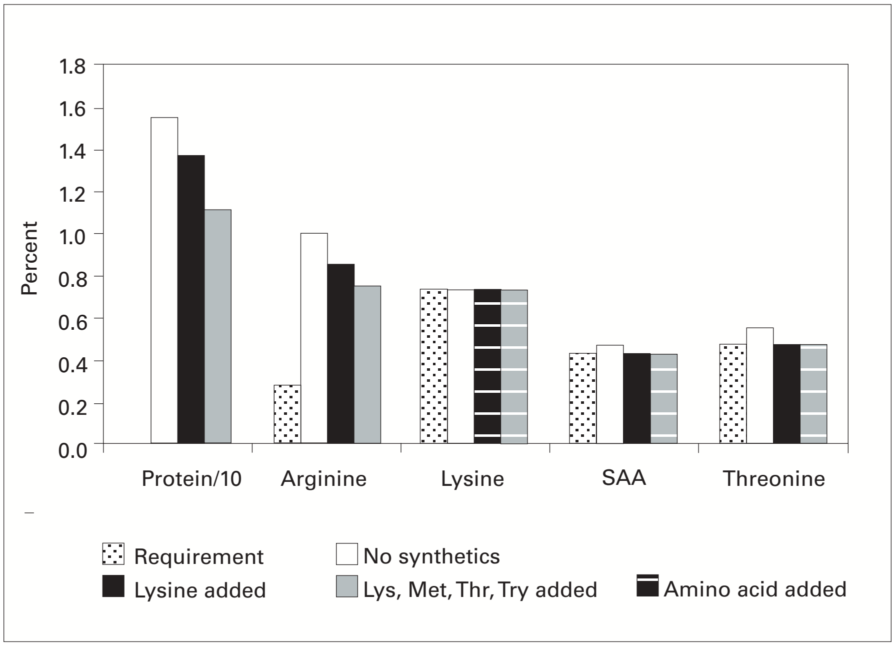

Figure 10-2. Dietary amino acid requirement for a 110-pound pig as per the NRC (1998) as matched with a corn soy diet without or with supplemental synthetic amino acids (lysine or lysine, methionine, threonine, and tryptophan). Hatched bars indicate that the amino acid was partially supplied in synthetic form. SAA are sulfur amino acids (methionine + cysteine).

...minimizing a diet's protein content not only substantially reduces N excretion in the manure but also reduces odor compounds in the manure.

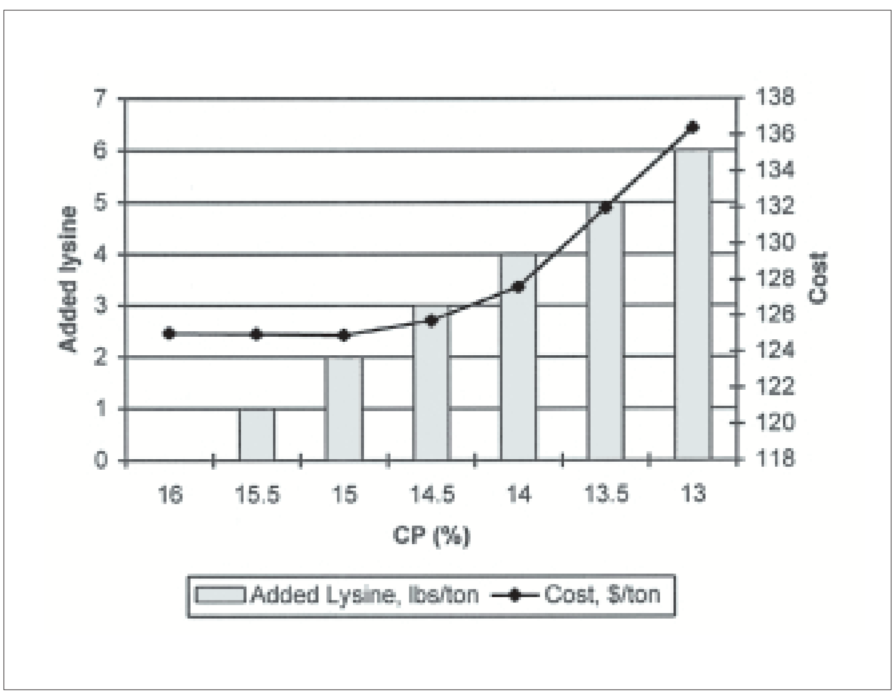

Figure 10-3. Cost or value of reducing crude protein (CP) in a C-SBM diet. Relevant ingredient prices used were as follows: corn, $90/ton; dehulled soybean meal, $180/ton; lysine-HCl, $1.09/lb; DL-methionine, $1.22/lb, threonine, $2.63/lb; and tryptophan, $15.80/lb.

Source: van Heugten and van Kempen 1998.

Table 10-4. Effect of adding crystalline amino acids to a C-SBM diet on the land application area required for a 1,000-head capacity pig-finishing facility.[1]

Diet Options	Manure N Excretion, lbs N/yr	Available N After Losses, lbs N/yr	Land Requirement for Managing N, acres
Systems that conserve nutrients (manure storage and incorporation during application)[5]			
C-SBM[2]	26,300	21,300	130
C-SBM + lysine[3]	22,900	18,500	113
C-SBM + lysine, tryptophan, threonine, and methionine[4]	16,600	13,400	82
Nutrient disposal system (anaerobic lagoon and pivot irrigation)[6]			
C-SBM[2]	26,300	4,000	25
C-SBM + lysine[3]	22,900	3,400	22
C-SBM + lysine, tryptophan, threonine, and methionine[4]	16,600	2,500	16

[1] Nutrient use in crop production assumed a corn (170 bushels/acre) and soybean rotation (50 bu/acre).
[2] Dietary CP level was 17.9%, 16.5%, 15.1%, and 13.0% for 45-80 lb, 80-130 lb, 130-190 lb, and 190-250 lb pigs, respectively.
[3] Dietary CP level was 16.4%, 14.9%, 13.6%, and 12.1% for 45-80 lb, 80-130 lb, 130-190 lb, and 190-250 lb pigs, respectively.
[4] Dietary CP level was 14.0%, 12.6%, 11.1%, and 9.6% for 45-80 lb, 80-130 lb, 130-190 lb, and 190-250 lb pigs, respectively.
[5] 80% of the N and 100% of the P are conserved.
[6] 20% of the N and 35% of the P are conserved in the wastewater to be pumped.
Source: Reese and Koelsch 1999.

manure. When comparing a commercial diet (18.9% protein) with a least-cost formulated low-protein diet (14.0% protein) in finisher pigs, p-cresol (the main odor-causing agent in swine manure, Schaefer 1977) decreased 43%; other odorous compounds measured decreased anywhere from 40% to 86%, depending on the compound.

To reduce overfeeding, it is important to understand the animal's nutritional requirements, the nutritional yield of feedstuffs, and the methods used to make the animal feeds. The nutritional requirements of animals are typically defined under laboratory-type conditions; animals are generally well cared for, and environmental conditions are maintained as close to optimum as possible. These requirements, though, do not necessarily translate to field conditions. As indicated before, the nutritional requirements of pigs can be calculated if the weight and the animal's actual protein growth are known (NRC 1998). Producers should attempt to obtain estimates of lean gain at their farm to better define the nutritional requirements of their animals.

...the nutritional requirements of pigs can be calculated if the weight and the animal's actual protein growth are known... .

Ideally, a computer model is used that can determine the ideal feeding program under a farm's varying conditions. For example, during hot weather, pigs tend to eat less while requiring extra energy for heat dissipation (heat loss). Thus, during hot weather, pigs should be fed a high-nutrient density diet with a lower protein-to-energy ratio than what is fed under standard conditions. Disease and stress have similar effects on the animal, calling for reduced protein-to-energy ratios.

As explained above, an animal's nutrient requirement changes with age (Table 10-5), sex, and growth potential. If the objective is to avoid wasting precious nutrients, then it becomes important to feed diets that are formulated to match the animal's nutrient requirement. Examples of this are split-sex feeding and phase feeding. For split-sex feeding, differences in nutrient requirements among gilts, barrows, and possibly boars are taken into consideration. Barrows typically have a higher feed intake capacity without a larger potential for lean gain, and thus diets should be fed with somewhat less protein.

Phase feeding refers to feeding programs that match the animal's nutrient requirement as this changes with the animal's age/size, as outlined in the Nutrient Use section. To minimize nutrient waste, the animal's diet should thus be changed continuously to match its requirements. Practically, going from a one-phase feeding program between 50 pounds and 250 pounds to a two-phase feeding program should reduce N excretion by 13%, while going to a three-phase feeding program should reduce N excretion by 17.5%.

From a practical perspective, it is not feasible to change the feed often, e.g., weekly, unless feeding equipment is available that is designed for this purpose. Table 10-6 indicates the feed costs savings that may be achieved by feeding in multiple phases (environmental benefits were not calculated for

From a practical perspective, it is not feasible to change the feed often, e.g., weekly, unless feeding equipment is available that is designed for this purpose.

Table 10-5. Ideal true digestible amino acid patterns for pigs in three different weight classes.

	Ideal Pattern, % of Lysine		
Amino Acid	**10-45 lbs**	**45-110 lbs**	**110-240 lbs**
Lysine	100	100	100
Threonine	65	67	70
Tryptophan	17	18	19
Methionine + Cystine	60	62	65
Isoleucine	60	60	60
Valine	68	68	68
Leucine	100	100	100
Phenylalanine + Tyrosine	95	95	95
Arginine	42	36	30
Histidine	32	32	32

Source: Baker 1996.

Table 10-6. Savings in feed costs with phase feeding for grow-finish pigs.

Number of Phases	Diet Cost/Pig	Savings over Two-Phase Program	Increase in Savings per Additional Diet
2	$42.44	—	—
3	$41.41	$1.14	$1.14
4	$41.01	$1.54	$0.40
5	$40.67	$1.88	$0.34
6	$40.43	$2.12	$0.24
9	$40.10	$2.45	$0.11
12	$39.90	$2.65	$0.06

Source: Koehler 1998.

this table), and based on this information, livestock producers should select the number of phases that fit their operation.

To feed pigs precisely, not only must the nutritional requirements of the pig and the nutrient yield of the feed be fully understood but also the capabilities of feed manufacturers to make these precision feeds. In general, feed manufacturers limit quality control to the measuring of N (crude protein), if that. Nitrogen, however, correlates poorly with the available amino acid content of feedstuffs (van Kempen and Simmins 1997), and feed manufacturers are, therefore, inclined to produce feed with a higher degree of variation than desirable for precision nutrition. Van Kempen and Simmins calculated that reducing the variation by using more appropriate quality control measures would result in a 13% to 27% reduction in N excretion. A prime example of such a quality control measure is to assess the nutritional value of each batch of a feedstuff, using, e.g., infrared spectroscopy, and to formulate feeds based on this nutritional value.

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Another potentially serious problem is the inability of some feedmills to properly weigh out ingredients. This problem is mainly precipitated by the use of the wrong scales (scales that are not precise enough for accurately weighing the call being made on them). Under practical conditions, this problem leads to an increase in weighing variation and typically overdosing of ingredients (van Kempen et al. 1999).

Phosphorus is typically overfed as well. Spears (Table 10-7) analyzed

Table 10-7. Requirement (Req.) for and concentrations of selected minerals in sow and grower-finisher feeds.

	Sow Diets			Finisher Diets		
Mineral	**Req.**	**Range**	**Median[1]**	**Req.**	**Range**	**Median[1]**
Calcium, %	0.75	0.62-2.01	1.21	0.50	0.57-1.38	0.96
Phosphorus, %	0.60	0.45-1.17	0.84	0.40	0.45-0.78	0.62
Copper, ppm	5	12-222	22	3	9–281	20
Zinc, ppm	50	79-497	167	50	103-205	149

[1]The median value indicates that 50% of the samples were below and 50% of the samples were above this value.
Source: Spears 1996.

Table 10-8. Effect of reducing dietary P level by 0.1% on the land application area required for a 1,000-head capacity pig-finishing facility.[1]

Diet Options	Manure P Excretion, lbs P_2O_5/yr	Available P After Losses, lbs P_2O_5/yr	Land Required to Manage P, acres
Systems that conserve nutrients (manure storage and incorporation during application)			
Normal C-SBM[2]	13,000	13,000	257
Reduced dietary P[3]	8,900	8,900	177
Nutrient disposal system (anaerobic lagoon and pivot irrigation)			
Normal C-SBM[2]	13,000	4,600	90
Reduced dietary P[3]	8,900	3,100	62

[1] Nutrient use in crop production assumed a corn (170 bushels/acre) and soybean rotation (50 bu/acre).
[2] Dietary P level in the diets was 0.60%, 0.55%, 0.50%, and 0.45% for 45-80 lb, 80-130 lb, 130-190 lb, and 190-250 lb pigs, respectively.
[3] Dietary P level in diets was 0.50%, 0.45%, 0.40%, and 0.35% for 45-80 lb, 80-130 lb, 130-190 lb, and 190-250 lb pigs, respectively. Dietary P level reduced by removing 11 lbs of dicalcium phosphate per ton of complete feed and substituting normal corn for low-phytate corn or adding phytase to normal corn-based diets.
Source: Reese and Koelsch 1999.

commercial feed samples and found that, on average, P was overfed 40% to 50% (depending on the production phase). Because it is likely that the land application rates of waste will be based on P in the near future, livestock producers may want to closely monitor the P intake of their pigs.

Phosphorus can be fed to maximize bone strength or to maximize performance. The maxima for each of these parameters is approximately 0.1% dietary P different, with maximum bone strength requiring more P. Especially for pigs targeted for slaughter, it may not be necessary to optimize the dietary P content for bone strength, which would lead to a large reduction in P excretion (Tables 10-7 and -8). Care, however, should be taken to avoid jeopardizing the welfare of the animals.

Jongbloed and Lenis's (1993) data suggest that the elements with potentially the largest threat for the environment are copper and zinc. Little research, however, has addressed this issue. Because copper and zinc are to a large extent used for pharmacological reasons, it seems that a simple (partial) solution to the copper and zinc problem is to reduce these minerals to the nutrient requirement level in the diet (Table 10-7).

To better match the feed's nutrient yield to the animal's nutrient need,

- Formulate feed on an available-nutrient basis.
- Include a disposal cost for nutrients in the formulation to find economical optima for their inclusion, rather than nutritional optima only.
- Implement phase feeding and split-sex feeding.
- Apply stringent quality control when preparing feed.
  –Determine the nutritional value of each batch of an ingredient.
  –Properly weigh and mix ingredients.

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- Formulate feed on an available-nutrient basis.
- Include a disposal cost for nutrients in the formulation to find economical optima for their inclusion, rather than nutritional optima only.
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- Apply stringent quality control when preparing feed.