SWINE TECHNOLOGY

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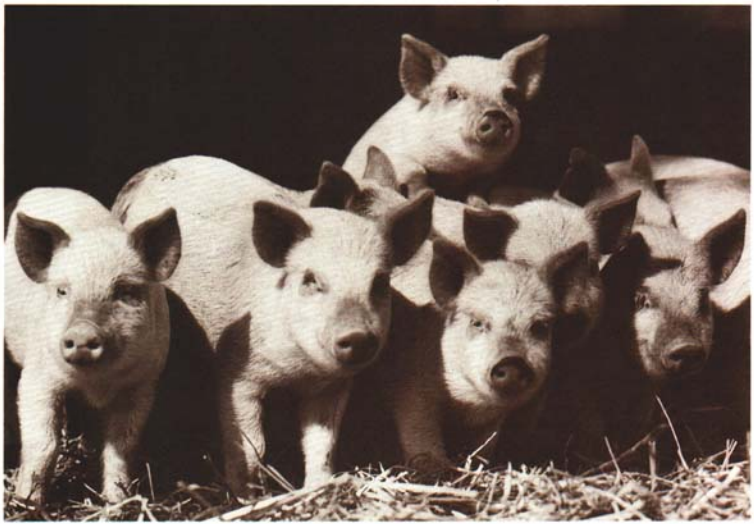
Nutrition:

SWINE FEEDS AND FEEDING



Sound nutrition from farrowing to market is the keystone of profitable swine management.

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SWINE FEEDS AND FEEDING

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FEED COSTS REPRESENT 65 to 80 percent of the total cost of producing hogs on Michigan farms. Therefore, a producer must have a thorough working knowledge of swine nutrition if the enterprise is to be managed efficiently. The fundamentals of animal nutrition and the nutrient requirements of swine are discussed in Extension Bulletin E-536.

This publication will show how the basic principles of nutrition can be applied to ration formulation.

Corn is the basic feed for hogs in Michigan, although it is deficient in many of the essential nutrients which they require. Correcting the deficiencies of corn and other cereal grains is the major concern in ration formulation.

Fortunately, producers have a wide variety of ingredients to choose from in formulating rations when price and availability justify. Each ingredient varies in quality and quantity of nutrients contained. But it should be emphasized that the pig has a requirement for *nutrients*, not particular ingredients. It makes no difference to a pig what the source of a nutrient is as long as it is present in the ration in adequate amounts and in a usable, palatable form. Therefore, judgement must be exercised in selecting the combination of ingredients which will result in optimum gain for the least cost.

Another consideration is that a particular feed may vary in composition. Corn produced this year is probably different from corn grown last year, even though both crops were harvested from the same field. The nutrient content of grains is affected by soil and climatic conditions during the growing period, stage of maturity at harvest, time in storage, etc. Animals, too, vary in their nutrient requirement. A ration that is nutritionally adequate for one hog may be inadequate for another. Thus, in ration formulation we are constantly dealing with variables and must base decisions on averages. Rations are usually over-fortified as an insurance factor to provide for the variation that exists in both feeds and animals.

Energy Feeds

Corn

Corn is an ideal hog feed because it is high in digestible carbohydrate (starch), low in fiber, and is a very palatable, safe feed that can be fed in a variety of ways. It may be fed shelled, ground, mixed, or free-choice, or even as ear corn. It may be dry or high moisture. It makes little difference to the pig; he likes corn any way it is offered.

In spite of its virtues, corn has many deficiencies that must be corrected (see Table 1). Corn contains 7 to 9 percent protein, but the protein is deficient in six of the essential amino acids required by the weanling pig, especially lysine and tryptophan. It is also so deficient in calcium and nine other mineral

Figure 1. — Good nutrition pays. These three littermate pigs were fed on different rations. Note how the performance has been affected.

elements and so inadequate in eight vitamins that pigs will die if they are limited to a ration containing only corn. So corn must be supplemented with a protein that makes up its amino acid deficiencies or with synthetic amino acids. Equally important are the needed minerals and vitamins. Properly supplemented corn is an excellent energy feed for all classes of swine.

Corn is now being bred that is much higher in lysine and tryptophan and hence has a better balance of amino acids for growing swine. The high-lysine corn (called opaque-2) is also higher in total protein than normal corn. Varieties of corn containing the opaque-2 gene are now commercially available but yields of these varieties are frequently less than that of regular varieties. They also vary significantly in their lysine concentration and a lysine analysis may be useful in determining nutritional value.

It should be noted that corn is higher in fat than barley or wheat (4 percent vs. less than 2 percent). This fat not only contributes to the high energy content of corn, but also improves its palatability and feeding properties in general.

Yellow corn is usually the cheapest source of energy, but price fluctuations frequently justify consideration of other feeds. The relative values of various feeds that may be used as complete or partial replacements for yellow corn in the swine ration are discussed below.

Barley

Barley is an excellent energy feed when corn is not available. Because of its higher fiber content (6 percent), barley has more bulk and is slightly lower in digestible energy. It contains more protein (11.5 percent) than corn, but the amino acid balance is not good. It does, however, contain about twice as much lysine as corn.

Barley should be ground to a medium degree of fineness or rolled for swine. When fed in this manner it can replace all or part of the corn in a swine ration. It is somewhat less palatable than corn. Thus, it is best to mix the ground barley with protein supplement rather than feed it free-choice. Pigs are less likely to overeat on protein supplement when fed by this method.

Moderate infestation of barley with scab renders it very unpalatable and may even be poisonous to pigs. Scabby barley should not be fed to lactating sows and small pigs.

Table 1. Nutrient deficiencies of corn for a 22 to 44 lb. pig raised in confinement when compared with the National Research Council (NRC) recommended nutrient requirements.

Protein and essential amino acids, %	NRC	Corn
Crude protein	18	8.8
Arginine	.23	.38
Histidine	.20	.22
Isoleucine	.56	.35[a]
Leucine	.68	1.06
Lysine	.79	.24[a]
Methionine + Cystine	.56	.32[a]
Phenylalanine + ½ tyrosine	.56	.64
Threonine	.51	.31[a]
Tryptophan	.15	.06[a]
Valine	.56	.44[a]

Energy, kcal/lb	NRC	Corn
DE	1600	1630
ME	1530	1550

Minerals, ppm	NRC	Corn
Calcium	6500	200[a]
Phosphorus	5000	2600[a]
Sodium	1000	100[a]
Chlorine	1300	500[a]
Potassium	3000	3000
Magnesium	400	1000
Sulfur	1000	1200
Iron	80	20[a]
Zinc	50	10[a]
Copper	6	4[a]
Manganese	20	6[a]
Iodine	0.2	?[a,b]
Cobalt	—[c]	?[b]
Selenium	0.1	0.04[a,b]

Vitamins (amount per kg)	NRC	Corn
A, IU	1750	600[a,d]
D, IU	200[e]	0[a]
D-α-tocopherol, mg	11	9[a]
K, mcg	?	?
Thiamin, mg	1.1	4
Riboflavin, mg	3.0	1.3[a]
Niacin, mg	18.0	21.4[a,f]
Pantothenic acid, mg	11.0	5.3[a]
Pyridoxine, mg	1.5	7
Biotin, mcg	?	?
Choline, mg	900	500[a]
B_{12}, mcg	15.0	0[a]
Folic acid, mcg	?	?
Ascorbic acid, mg	0	?

[a] *Corn is deficient in these nutrients for the growing pig.*
[b] *Will vary with soil levels. Very low in most Michigan corn.*
[c] *Cobalt requirement met as a constituent of vitamin B_{12}.*
[d] *Vitamin A equivalent from corn carotenes.*
[e] *Less if pigs receive some direct sunlight daily.*
[f] *All niacin in corn is thought to be bound and unavailable.*

DE = digestible energy; ME = metabolizable energy; Kcal = kilocalories; ppm = parts per million; ? = requirement not determined or analysis not available.

Oats

As an energy feed, oats are handicapped by their high fiber content (10 to 15 percent). This bulk makes oats a better feed for breeding animals than for young pigs or finishing animals where high energy rations are needed for fast gains. Protein content averages about 12 percent.

Oats vary greatly in test weight, and hence the feeding value also varies. Fine grinding or removal of the hull improves the feed efficiency. When ground oats comprise no more than 30 percent of the ration, the growth rate of growing pigs will be reduced very little, if at all. Oats have a lower feeding value on pasture because the pasture forage is also bulky and fibrous.

If the hulls are removed and the groats rolled, the product is an excellent feed, particularly in starter rations for baby pigs.

Wheat

For all practical purposes, wheat is equivalent to corn as a source of energy and is slightly superior in protein (quality and quantity). It can be used as a pound-for-pound substitute for corn, but because of cost, it is not widely used in swine feeding. Low quality wheat not suitable for milling (feed grade wheat), as well as damaged wheat, can be profitably utilized by swine.

Wheat should be ground coarsely or rolled for hogs. When ground too finely, it has a tendency to form a pasty mass in the mouth and becomes less palatable.

Sorghum Grain (Milo)

Sorghum grain is the corn equivalent of the Southwest and other areas, where it has production advantages over corn. Because it has many of the same virtues (except it contains no carotene) and deficiencies as corn, it can replace corn in all swine rations. The kernel is hard and small and should be ground and mixed with other ingredients.

Rye

Rye is a rather unpalatable cereal grain that should not make up more than 20 percent of the swine ration. Since its kernels are smaller and harder than those of corn, the best results will be obtained by feeding it ground rather than whole.

Rye is often infested with the fungus, ergot. Since ergot may cause abortion, rye infested with it should never be fed to pregnant sows. The fungus reduces feed consumption and growth rate when fed to growing-finishing swine.

Triticale

Triticale is a hybrid obtained by crossing wheat and rye. It is lower in digestible energy than corn but higher than barley. It contains from 12 to 15 percent crude protein and is about equal to barley in lysine concentration (0.5 percent). Some studies with growing-finishing pigs have suggested that because of somewhat lesser palatability, triticale should not constitute more than 50% of the ration. When used in this way its feed value is similar to that of wheat (Table 2).

Certain varieties of triticale may be prone to infestation with ergot. When ergot infestation is present, this grain should not be fed to pregnant sows.

Cull Beans

Frequently cull beans are available in quantity and can serve as another feed for hogs. They should be boiled or cooked by steam to improve the palatability and feeding value.

Beans should not comprise more than one-third of the ration (dry weight before cooking) for pigs weighing up to 100 pounds. They may be increased later to one-half the ration, and when very cheap, may constitute the main part of the growing-finishing ration. The labor and cost of cooking must be included when determining how much to pay for them.

Although beans are fairly rich in protein (20 to 23 percent), the protein is of very poor quality. At least one-half pound of a good protein supplement should be fed per head daily to growing-finishing pigs to correct the deficiencies of beans.

Cull Potatoes

Potatoes contain only about 23 percent as much dry matter as shelled corn, and the dry matter contains little except carbohydrates (starch). Thus, a good protein supplement should be fed along with vitamins and minerals. Hogs over 100 pounds in weight make the most satisfactory use of potatoes. For best results, potatoes should be cooked. Add salt to the water in which the potatoes are cooked to increase their palatability. The potatoes should be cooked thoroughly and the water drained off before feeding.

Bakery Waste

Stale bread, bakery crumbs, cookies and crackers are high carbohydrate products that may or may not contain a considerable amount of added fat. The protein content averages about 10 percent, but no reliable amino acid analysis figures are available. These products should be considered energy substitutes for corn up to about 50 percent of the ration. In this case, the value is about equal to that of corn. When cheap enough, they may replace all the corn. Protein, mineral, and vitamin supplementation recommendations are the same as for the cereal grains.

One of the difficulties often associated with feeding bakery by-products is the labor of removal, separation and disposal of wrappers and cartons.

Fat, Tallow, Greases

These products are now available as very high energy sources (2.25 x the gross energy of carbohydrates). The amount used in swine rations is usually less than 5 percent. Adding a higher percentage of fat to the ration may result in fatter carcasses and a depression of feed intake. Feed efficiency is improved when fat is added because of its very high digestible energy (DE), but since energy is its only contribution, the need for proper supplementation is increased. There are no proteins (amino acids), minerals, or vitamins in fats. Rancidity in fats should be prevented by including an antioxidant such as ethoxyquin at 0.0125 percent.

Molasses

Molasses, either cane or beet, is a carbohydrate source that can be substituted for a part of the grain. It should be limited to about 5 percent of the ration and when used in this manner is worth approximately 60 percent as much as corn. Too much molasses causes scours.

Calculating the Value of Corn Substitutes

The value of a corn substitute is related to its lysine and digestible energy content and the value of the pounds of corn and soybean meal it replaces. As the price relationship between corn and soybean

Table 2. Formula for calculating the dollar value of corn substitutes in a MSU 16 grower ration.

				Formula per cwt. grower (MSU 16) ration[a]				
Feedstuff	Maximum in ration %	Rel. DE[b]	Lysine %	Corn lb.	Max. subs. lb.	SBM (44) lb.	Vit. min. premix lb.	Relative value of substitute (cents per lb.)[c]
Corn	No limit	1.00	.25	77	0	20	3	C
Hi lysine corn	No limit	1.00	.40[d]	0	82	15	3	(77C+5S)÷82
Barley	No limit	.88	.35	0	80	17	3	.88(77C+3S)÷80
Oats	30	.81	.35	48	30	19	3	.81(29C+1S)÷30
Wheat	No limit	1.00	.30	0	78.5	18.5	3	(77C+1.5S)÷78.5
Milo	No limit	.97	.20	0	75.5	21.5	3	.97(77C−1.5S)÷75.5
Rye	20	.90	.45	58.5	20	18.5	3	.90(18.5C+1.5S)÷20
Dehulled oats	No limit	1.02	.45	0	83.5	13.5	3	1.02(77C+6.5S)÷83.5
Bakery waste	50	1.00	.25	27	50	20	3	C
Cull beans (cooked)	50	.83	.45	31	50	16	3	.83(46C+4S)÷50
Cull potatoes (cooked)	25	.25	.10	50.5	25	21.5	3	.25(26.5C−1.5S)÷25
Tallow	5	2.40	0	72	5	20	3	2.4C
Lard	5	2.30	0	72	5	20	3	2.3C
Molasses								
Beet	5	.65	.20	72	5	20	3	.65C
Cane	5	.65	.15	72	5	20	3	.65C
Wheat middlings	20	.85	.60	60	20	17	3	.85(17C+3S)÷20
Wheat bran	20	.72	.60	60	20	17	3	.72(17C+3S)÷20
Triticale	50	.95	.45	31	50	16	3	.95(46C+4S)÷50

[a] *Calculated to provide .75% lysine in ration. Lysine value of 2.8% used for soybean meal (44%).*
[b] *Relative digestible energy.*
[c] *C: Current price of corn (cents per pound); S: current price of soybean meal (44%) (cents per pound).*
[d] *Lysine concentration is variable and should be determined by assay.*

meal changes so does the relative value of the corn substitute.

Tables 2 and 3 are designed to assist producers with calculating the relative value of corn substitutes by applying the existing market price of ingredients. For example, suppose a producer must buy feed and he has a choice of buying corn at 4 cents per pound or barley at 3.5 cents. Soybean meal is selling for 10 cents per pound. Which grain is the better buy? The formula for MSU 16 grower ration is 77 pounds of corn, 20 pounds of soybean meal and 3 pounds of minerals and vitamins (Table 2). Line 3 shows 80 pounds of barley will replace all the corn and require 3 pounds less of soybean meal (20-17=3). A pound of barley would be worth:

$$77 \times 4^{¢} + 3 \times 10^{¢} =$$
$$308^{¢} + 30^{¢} = 338^{¢}$$
$$338^{¢} \div 80 \text{ lb.} = 4.2^{¢}$$

However, barley has only 88% the digestible energy of corn so the price per pound must be multiplied by .88 to correct the difference. Thus, the true value of a pound of barley would be 3.7 cents.

$$4.2^{¢} \times .88 = 3.7^{¢}$$

The prices used in this example show barley at 3.5¢ per pound is a better buy than corn at 4¢ per pound. By solving the equations in the last column of the tables, the relative value of various ingredients can be computed.

Protein Feeds

Protein is made up of 22 or more nitrogenous compounds called amino acids. Protein feeds vary in the kind and amount of amino acids they contain. During the digestion process, the protein in feed is broken down into the various amino acids and the pig recombines them into the kind of protein needed for muscle development, repair of worn-out tissue, etc. Thus, the real need of the pig is for amino acids, not protein as such.

The pig can synthesize some of the amino acids so they are not required in the diet. However, ten of the amino acids are termed "essential" because the body cannot manufacture them in sufficient quantity to permit maximum growth. It is important that ingredients rich in the essential amino acids be used in formulating the ration.

Although it is a common practice to refer to "percent protein" in a ration, this term has little meaning unless there is knowledge concerning the amino acids present. A protein feed is considered to be of good quality when it contains all the essential amino acids in the proportion and amount needed by the pig.

Soybean Meal

Soybean meal is usually the most economical source of good quality protein available to Michigan swine producers and is the basic ingredient in commercial protein supplements. It is marginal in methionine but otherwise very well-balanced in amino acids. Soybean meal must be supplemented with minerals and vitamins, and usually cannot be fed free-choice because of its high palatability. Pigs are inclined to eat more than is needed to meet their protein needs.

Producers have a choice of buying either a 44 or 49 percent soybean meal. The 49 percent meal is the most desirable to use in pre-starter and starter rations because much of the hull has been removed.

Table 3. Formula for calculating the dollar value of corn substitutes in a MSU 13 finisher ration.

				Formula per cwt. finisher (MSU 13) ration[a]				
Feedstuff	Maximum in ration %	Rel. DE[b]	Lysine %	Corn lb.	Max. subs. lb.	SBM (44) lb.	Vit. min. premix lb.	Relative value of substitute (cents per lb.)[c]
Corn	No limit	1.00	.25	85	0	12	3	C
Hi lysine corn	No limit	1.00	.40[d]	0	90	7	3	(85C+5S)÷90
Barley	No limit	.88	.35	0	88.5	8.5	3	.88(85C+3.5S)÷88.5
Wheat	No limit	1.00	.30	0	86.5	10.5	3	(85C+1.5S)÷86.5
Milo	No limit	.97	.20	0	83.5	13.5	3	.97(85C−1.5S)÷83.5

[a] *Calculated to provide .55% lysine in ration. Lysine value of 2.8% used for soybean meal (44%).*
[b] *Relative digestible energy.*
[c] *C: current price of corn (cents per pound); S: current price of soybean meal (44%) (cents per pound).*
Note: Figures for other ingredients listed in Table 2 would remain practically the same.
[d] *Lysine concentration is variable and should be determined by assay.*

Thus, it has less fiber (3 percent), is higher in energy, and more palatable. Growing-finishing pigs can utilize both meals about equally. The price per unit of protein will determine which is the better buy. The following example explains how to calculate the comparative advantage. Assuming that 44 percent meal can be purchased for $160 per ton, what would a ton of 49 percent meal be worth?

$$44\% : \$160.00 :: 49\% : X$$
$$44X = 7840$$
$$X = 7840 \div 44 = \$178.18$$

Thus, on a protein equivalent basis, a 44 percent soybean meal costing $160 per ton would be equal in value to a ton of 49 percent meal costing $178.18 per ton.

However, there are other factors to take into consideration. It requires fewer pounds of 49 percent meal to balance a ton of complete feed than it does of 44 percent meal. In most cases the difference will figure about 50 pounds. This means that a ton of total ration supplemented with 49 percent meal will contain 50 pounds more corn. The cost of the extra corn must be charged against the 49 percent meal when calculating which meal is the most economical. Thus, if corn is worth 4 cents per pound (50 x .04 = $2.00), a ton of 49 percent soybean meal would be worth only $176.18 ($178.18-2.00) in the preceding example.

Another economic factor to take into consideration when deciding between a 44 and 49 percent meal is that 44 percent meal will often actually test 45 or 46 percent crude protein. This "overage" is usually higher for 44 than 49 percent meal. Thus, a person may get a little more for his money when he buys 44 percent meal.

Heat Treated Soybeans

Raw soybeans contain approximately 37 percent protein and 18 percent fat. The fat provides available energy but the protein is poorly utilized by pigs because the soybeans contain antitrypsin which inhibits protein digestion. Heat will destroy this enzyme inhibitor.

Three types of cooking equipment using different methods of processing are available. These are infra-red cookers, expander-extruder cookers, and high-pressure steam cookers. All are fairly expensive. An investment in this type of equipment commits the operator to long-term use even though relative prices of raw beans and soybean meal may not justify the practice. Hogs fed cooked soybeans tend to have softer carcass fat, particularly those that are inclined to be overly fat.

Research indicates that feed efficiency is improved between 5 and 10 percent when meal is replaced by cooked beans. However, due to the lower protein content of cooked beans as compared to meal, it requires about 2,350 pounds of beans to equal the protein in 2,000 pounds of 44 percent soybean meal. Grower and finisher ration formulas using heated soybeans are given in Table 4.

Table 4. Formulation of MSU 16 grower and MSU 13 finishing rations with heated soybeans.

Ingredient	Pounds per ton	
	MSU 16 Grower	MSU 13 Finisher
Corn	1370	1580
Heated soybeans (37%)	530	320
MSU mineral-vitamin supplement[a]	100	100
	2000	2000

[a] *See Table 19.*

Meat and Bone Meal, Tankage, Fish Meal

These animal proteins are standard sources of protein widely used in swine rations. They are deficient in the amino acid tryptophan, so they should not be used as a single source of protein. When priced low enough, these proteins can furnish up to 50 percent of the protein in a supplement. They are good sources of calcium and phosphorus, but are not as palatable as soybean meal.

Linseed Meal

Linseed meal is too deficient in lysine to be used extensively as a protein supplement with cereal grains. It is fairly well-liked and, because of its slightly laxative properties, it is used in limited amounts in brood sow rations. It contains almost twice as much calcium as cottonseed and soybean meal, and is about the same in B vitamin content. Linseed meal should not make up more than 20 percent of the total protein supplement.

Cottonseed Meal

This protein is not widely used in swine feeding because of gossypol, a toxic substance present in variable amounts in some cottonseed meals. If the amount of free gossypol is known to be low, cottonseed meal can be used to supply 20 percent of the

supplemental protein. The protein of cottonseed meal is deficient in lysine and marginal in isoleucine, threonine and tryptophan. Cottonseed meal is low in calcium, fairly high in phosphorus (but of questionable availability), and fair in B vitamin content. It is not a very palatable supplement for pigs.

Milk Products

The milk products which are used in swine feeding are liquid and dried whey, dried skimmed milk and dried buttermilk. Whey is the serum or liquid by-product of cheese manufacture. Casein and butterfat are removed from milk in the process. Thus, whey consists of water, non-casein milk protein, lactose and minerals. Whey may be taken from the cheese factory to the farm and fed as liquid whey or it may be commercially dried by a spray or roller drying process and marketed as dried whey to the feed or livestock industry.

Dried skimmed milk and dried buttermilk consist essentially of non-fat milk solids. Dried buttermilk has more fat but somewhat less protein than dried skimmed milk. Whey, dried skimmed milk and dried buttermilk are all good sources of calcium and phosphorus. The approximate nutrient composition of these milk by-products is presented in Table 5.

Whey

Liquid whey contains only about 6% dry matter, which is largely lactose. The low concentration of dry matter limits the use of whey as an energy source and the high lactose content reduces it usefulness as a feed for older pigs. Baby pigs can utilize lactose efficiently; however, the efficiency of utilization decreases with age due to a reduced level of intestinal lactase activity in the older pig. Growing-finishing pigs will consume a high level of the liquid whey if dry feed intake is limited. For example, if a 100 lb. pig is limited to 2½ pounds of a balanced ration daily he may consume up to 3 or 4 gallons of liquid whey daily.

There are a number of ways in which liquid whey can be utilized by growing-finishing pigs. One way is to limit pigs to about one-half of their normal intake of a balanced ration to encourage maximum consumption of whey. Another method is to full feed a ration with reduced protein, calcium and phosphorus levels and removal of salt from the ration to take advantage of these nutrients in the whey. Thus, rations shown in Table 6 could be placed in a self feeder for growing-finishing pigs with whey also continuously available. Gestating sows and gilts would be fed a limited amount of the ration shown and lactating sows and gilts could be hand-fed or full-fed. Another method for feeding whey to growing-finishing pigs would be to self-feed ground grain and liquid whey and hand feed ½ pound of a complete supplement per head per day.

In terms of nutrient value, it takes about 2 gallons of 6% dry matter liquid whey to be worth a pound of a complete dry feed.

Condensed whey containing 35 to 60% dry matter is sometimes available and can either be diluted

Table 5. Nutrient composition of some milk by-products.

Nutrient	Liquid whey	Dried whey	DWP[a]	DSM[b]	DBM[c]
Water, %	94	6	6	6	7
Protein, %	1	12	16	34	32
Fat, %	0.1	1	1	1	6
Lactose, %	4	68	52	51	44
Minerals, %	0.6	10	15	8	10
Calcium, %	0.06	0.9	1.5	1.3	1.3
Phosphorus, %	0.05	0.7	1.0	1.0	1.0
Sodium, %	0.07	1.0	1.5	0.5	1.0
DE, kcal/lb.	90	1400	1300	1700	1550
Riboflavin, mg/lb.	1	14	24	9	14
Niacin, mg/lb.	0.3	5	10	5	4
Pantothenic acid, mg/lb.	1.5	22	32	15	14
Vitamin B_{12}, mcg/lb.	0.1	12	15	27	9
Choline, mg/lb.	60	1100	1800	800	700
Lysine, %	0.06	1.0	1.5	2.6	2.4
Methionine + cystine, %	0.05	0.8	1.1	1.3	1.1
Tryptophan, %	0.01	0.2	0.3	0.4	0.4

[a] *Dried whey product.*
[b] *Dried skimmilk.*
[c] *Dried buttermilk.*

Table 6. Rations which may be fed with liquid whey continuously available.

Ingredient	(30-75 lb) Grower	(75-125 lb) Developer	(125-220 lb) Finisher	Gestation	Lactation
Ground grain (corn, oats, wheat, milo or combination)	1750	1800	1850	1850	1750
40% Commercial suppl.	250	200	150	150	250
- or -					
Soybean meal 49	210	160	110	105	205
Dicalcium phosphate	15	15	15	20	20
Ground limestone	14	14	14	14	14
Vitamin-trace mineral premix	10	10	10	10	10
Selenium premix	1	1	1	1	1
Total	**2000**	**2000**	**2000**	**2000**	**2000**
Method of feeding	Self-fed	Self-fed	Self-fed	Hand-fed	Self- or hand-fed
Average daily feed, lb.	2-3	4	5-6	3	10
Expected daily liquid whey consumption, lb.	10	15	20	15	20

and handled as liquid whey or made available in condensed form free-choice with fresh drinking water constantly available. Grain and supplement feeding would be similar to that for liquid whey feeding programs.

Dried whey or dried whey product, which is a partially delactosed whey, may at times be economically included in starter, grower and finisher rations. It can be fed at higher levels but it is generally a safe rule to limit the dried whey or dried whey product to 20% of the starter ration and 10% of grower and finisher rations to avoid causing diarrhea or reducing rate of gain. Dried whey makes an excellent binder in pelleted rations although care has to be exercized in the pelleting process that excessive heat is not applied or else some of the lysine in the ration may become unavailable due to a browning reaction of the lactose in the whey. An example of the use of dried whey product in a starter ration is shown in Table 25.

Alfalfa Meal (Dehydrated)

Although it contains 17 to 20 percent protein alfalfa meal is not fed as a source of protein. It is a substitute for pasture and is a good source of carotene (vitamin A) and the B vitamins (riboflavin, pantothenic acid, niacin). Because of its high fiber (25 to 30 percent) and low palatability, it is used in limited amounts in growing-finishing rations (2 to 5 percent).

The relative values of the various sources of protein for swine rations are presented in Table 7. Recommended levels of protein in swine rations and expected daily ration consumption are presented in Table 8.

Vitamins

Many of the vitamins required by swine are present in adequate amounts in natural feedstuffs, so they are not of practical concern. Those that are likely to be deficient can be divided into two groups.

Fat Soluble Vitamins

Vitamin A
Vitamin D
Vitamin E
Vitamin K

Water Soluble Vitamins

Riboflavin
Niacin
Pantothenic Acid
Choline
Vitamin B_{12}

Recommended levels of these vitamins in swine rations are presented in Table 9.

There are three of the above vitamins which should receive special attention. Yellow corn contains the pigment, carotene, which can be converted to biologically active vitamin A in the intestinal wall of the pig. However, swine are not efficient converters of carotene to vitamin A, and much

Table 7. Relative value of various sources of protein.[a]

Source of protein	Relative value (percent)
Soybean meal (44% protein)	100
Cottonseed meal	85
Linseed meal	80
Distillers solubles, dried	77
Fish meal (menhaden)	130
Meat and bone meal (50% protein)	100
Tankage (60% protein)	110
Blood meal	123
Skim milk, dried	100

[a] *The relative values listed above are based upon the amount of supplement required in a 16 percent protein ration containing 50 percent of the recommended level of 44 percent soybean meal. In general, the values reflect the ability of the supplement to provide the essential amino acid, lysine.*

Table 8. Recommended protein levels and approximate daily feed intake.

	Percent protein in ration	Average daily feed intake (lbs.)
Growing:		
Creep rations (suckling)		
10 to 30 lbs.	18	0.4
Starter - 20 to 40 lbs.	18	2.3
Grower - 30 to 125 lbs.	16	4.5
Finisher - 125 lbs. to 215 lbs.	13	7.0
Breeding season:		
Gilts	13	7.0
Sows	13	6.0
Gestation:		
Gilts	13	5.0[a]
Sows	13	4.0[a]
Lactation:		
Gilts and sows	16	12.0
Breeding boars	16	6.0

[a] *These amounts can be reduced to 4.0 and 3.0 pounds if on pasture.*

of the carotene may be destroyed in storage. Therefore, in formulating swine rations, the carotene content of yellow corn is disregarded.

Similarly, niacin in yellow corn and other cereal grains exists in a bound form that is largely unavailable to swine. For this reason, yellow corn is not credited with containing any niacin. If the ration is rich in the amino acid, tryptophan, it can be converted by the pig to niacin.

Until recent years, vitamin E was thought to be associated only with reproductive efficiency. However, since 1968, numerous pigs (20 to 100 pounds) examined in the MSU necropsy laboratory exhibited typical lesions of vitamin E deficiency.

Frequently the first sign of trouble was sudden death in weaned pigs, particularly following a stress period such as co-mingling of litters. Occasionally the animals would be anemic and show signs of jaundice. Edema, white muscle and liver damage (Fig. 2) were common. In general, the pigs and their dams had been raised in confinement on corn-soy diets.

There is growing evidence that a decline in the use of pasture and the artificial drying of grains has significantly reduced vitamin E intake. Feed grains grown on soils low in selenium are usually found to

Figure 2. — Pig liver showing the mottled appearance frequently seen in vitamin E and/or selenium deficiency.

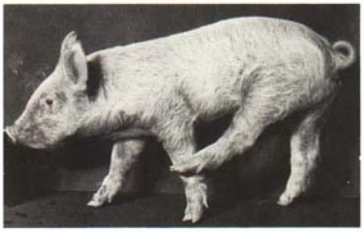

Figure 3. — Pantothenic acid-deficient pig showing the characteristic "goosestepping". The condition is due to deterioration of the sciatic nerves when the supply of the vitamin, pantothenic acid, is not adequate.

Figure 4. — Vitamin D-deficient baby pig exhibiting rickets. Limbs are shortened, pasterns are weak, legs are crooked and the pig can barely walk. Pig received adequate levels of all nutrients with the exception of vitamin D.

be low in that element. The exact relationship between vitamin E and selenium has only been partially defined, but the requirement for vitamin E increases as the selenium content of natural feeds decreases.

The FDA has approved the addition of 0.1 ppm of selenium to all swine rations. With the addition of selenium to the ration the requirement for vitamin E can probably be assured by including 5,000 IU per ton in all swine rations.

While vitamin K may be provided in natural feedstuffs or by microbial synthesis in the intestinal tract, moldy feeds may occasionally contain anti-vitamin K compounds. Hemorrhage may be noted from the umbilical cords of baby pigs or after castration. Supplementation with 2 to 4 grams of a vitamin K compound per ton of complete feed may be helpful in preventing this problem.

Natural Sources of Vitamins

A (or carotene) — Alfalfa meal, good pasture, fish liver oils.

D — Irradiated yeast, sun-cured meals and hays, and exposure to sunshine.

E — Legume pasture and alfalfa meal.

K — Legume pasture and alfalfa meal.

Water soluble vitamins (other than B_{12}) — Alfalfa meal, distiller solubles, condensed fish solubles, milk by-products, good pasture.

B_{12} — Animal proteins, condensed fish solubles, and distiller solubles.

Synthetic Vitamins

In addition to the natural sources of vitamins listed above, many companies are supplying synthetic vitamin concentrates which are relatively inexpensive. The vitamins may be purchased individually or in combinations.

Minerals

Minerals constitute a small percentage of the swine ration, but their importance to the health and well-being of the pig cannot be overemphasized. The ones that are most likely to be lacking in swine rations and practical sources are:

Mineral	Source
Calcium	Feeding limestone, bone meal, dicalcium phosphate, defluorinated rock phosphate.
Phosphorus	Dicalcium phosphate, bone meal, defluorinated rock phosphate.
Sodium and Chlorine	Salt.
Trace Minerals	
Iron Copper Iodine Manganese Zinc Selenium	May be provided in a special swine trace-mineral salt or in a trace mineral premix. Selenium is generally available in a separate premix (Table 18).

Suggested levels of these minerals in swine rations are given in Table 10.

Table 9. Recommended vitamin levels for dry-lot, corn-soy rations.

	Creep and starter ration	Grower ration	Finisher ration	Breeder ration
Fat-soluble vitamins				
Vitamin A, IU per lb.	1,500	1,500	750	2,500
Vitamin D, IU per lb.	500	300	300	300
Vitamin E, IU per lb.	5	5	5	5
Vitamin K, mg per lb.	1	1	1	1
Water-soluble vitamins				
Riboflavin, mg. per lb.	1.5	1.4	1.0	1.8
Nicotinic acid, mg. per lb.	10.0	8.0	5.0	10.0
Pantothenic acid, mg. per lb.	6.0	5.0	5.0	6.0
Choline, mg. per lb.	500.0	400.0	350.0	350.0
Vitamin B_{12}, mcg. per lb.	10.0	7.0	5.0	7.0

Calcium and Phosphorus Fortification

The ingredients of swine rations vary widely in mineral content. Corn and soybean meal are particularly low in calcium. Feed grains contain phosphorus, but it is largely phytin phosphorus, which may be poorly utilized by swine. Corn-soybean meal rations must therefore be supplemented with both calcium and inorganic phosphorus.

Feeds of animal origin such as meat and bone meal, tankage, and fishmeal are quite high in calcium and phosphorus. The level of calcium, and especially phosphorus supplementation, should be reduced as feeds of animal origin replace soybean meal in the swine ration.

The standard ingredients for supplying supplemental calcium and phosphorus in the swine ration are limestone and dicalcium phosphate. Dicalcium phosphate is often in short supply and substitutions

Table 10. Amounts of calcium, phosphorus and trace-mineral salt that should be present in the total ration of hogs of various ages.

Mineral	Creep, percent	Breeder and grower, percent	Finisher, percent
Calcium	0.80	0.75	0.50
Phosphorus	.60	.50	.40
Trace-mineral salt	.50	.50	.50

Table 11. Feed ingredients which supply calcium or calcium and phosphorus.

	% Ca	% P	Lbs. needed to equal P in 1 lb. of dicalcium phosphate	Lbs. change in limestone for each lb. change of dical.
Ground limestone (calcium carbonate)	38	0		
Dicalcium phosphate	26	18		
Monocalcium phosphate	18	18	1	+.2
Mono-dicalcium phosphate	22	18	1	+.1
Defluorinated rock phosphate	32	18	1	−.2
Steamed bone meal	26	13	1.4	−.3
Tricalcium phosphate	38	18	1	−.3
Meat and bone meal	10	5	3.7	−.3
Tankage	6	3	6	−.3
Fish meal	6	3	6	−.3

must be made. Table 11 lists a number of phosphorus sources which may be used to replace dicalcium phosphate. It should be noted that all of the ingredients, like dicalcium phosphate, supply both calcium and phosphorus. Thus, the quantity of limestone in the ration must also be adjusted when phosphorus substitutions are made.

The last two columns in Table 11 list the correction factors that must be applied to the pounds of limestone and dicalcium phosphate in the ration when substitutions are made. For example, if steamed bone meal were substituted into a ton of grower ration where 20 pounds of dicalcium phosphate and 20 pounds of limestone have been used, the factor of 1.4 would be applied to the 20 pounds of dicalcium phosphate giving 28 pounds of steamed bone meal needed (20 times 1.4=28). Both dicalcium phosphate and steamed bone meal contain 26 percent calcium. When 8 pounds more of steamed bone meal are used than the 20 pounds of dicalcium phosphate, the limestone must be reduced by the factor -.3 or -2.4 pounds (8 times -.3 = −2.4). Thus, 28 pounds of steamed bone meal and 17.6 pounds of limestone would be mixed in the ration.

The following mineral mixture, when provided in a ton of a corn-soybean meal ration, will meet the minimal needs of growing-finishing pigs.

Mineral Mixture

20 lb. — Limestone

20 lb. — Dicalcium phosphate

10 lb. — Trace-mineral salt (high zinc — .8%)

It will contain 26 to 27 percent calcium, 5.5 to 7.0 percent phosphorus, and 20 percent salt.

Zinc Supplementation

The natural feedstuffs in a ton of conventional growing-finishing ration will supply approximately 30 to 35 parts per million of zinc. Adding 10 pounds of trace-mineral salt containing .8 percent zinc will furnish an additional 40 parts per million of zinc to the diet. Normally, this quantity of zinc is adequate to prevent a mange-like skin condition known as *parakeratosis*. Signs of this condition are slow growth, unthriftiness, harsh dry hair coat, development of reddened areas, and a thickening and encrusting of the skin on the legs, ears, hams and belly (Fig. 5).

High levels of calcium (over .75 percent) in the ration increase the requirement of zinc. Early weaned pigs (3 weeks) also appear to have a greater requirement for zinc than older pigs. Under these conditions, an additional supplement of 40 parts per million of zinc may be needed, in addition to that supplied by the natural feeds and trace-mineral salt, to prevent parakeratosis. The compounds listed in Table 12 may be used for any needed zinc fortification.

Table 12. Recommended zinc compounds and the amount needed to furnish 40 parts per million of zinc.

Compound	Zinc content (percent)	Grams to add per ton of complete ration
Zinc oxide (ZnO)	80	46
Zinc carbonate ($ZnCO_3$)	56	65
Zinc sulfate ($ZnSO_4.H_2O$)	36	102

Precautions on Mineral Feeding

Many nutrients such as certain vitamins can be fed in excessive amounts without affecting the performance of the pig. Only the farmer's pocketbook is hurt. This is not true in the case of minerals. Excessive feeding or an improper balance of minerals will depress rate of gain and general performance of pigs as much as feeding inadequate amounts.

Never mix additional minerals with a commercial protein supplement unless the need is specified on the tag. A good mineral mixture can be fed free-choice without danger, if there is any question about adequate mineral fortification.

Water

Water is so common we seldom think of it as a nutrient. But water is the largest single part of nearly all living things. Hogs need to have plenty of clean, fresh water at all times. It is particularly important to supply suckling pigs with water if a high intake of creep ration is to be obtained. Rate of gain and milk flow are also affected by water consumption. Estimates of daily water consumption are given in Table 13.

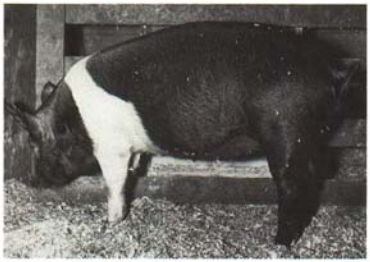

Figure 5. — The 10-weeks old pig (top) exhibits the typical symptoms of "parakeratosis" resulting from a zinc-deficient diet. The same pig (bottom) at six months after receiving a ration containing 100 parts per million of zinc.

Feed Additives

Additives used in swine rations include (1) antibiotics, (2) arsenicals, and (3) copper compounds. These are not true nutrients, since they are not required for normal growth. They apparently have an influence on intestinal microorganisms and improve the health of the animal. Prolonged and excessive use of feed additives may interfere with the intestinal synthesis of certain vitamins.

All farms have an "environmental disease level". The greater the disease build-up, the greater the response to feed additives. Pigs up to 100 pounds in weight usually give a greater response than older hogs. Although feed additives can help control disease problems, they should never be considered a substitute for good management.

Continuous feeding of the same additive may decrease its effectiveness. Periodic changing of drugs seems to be the best approach. The best time to rotate additives is when major changes are made in the ration, such as going from a grower to a finishing ration.

Certain feed additives may be absorbed and retained in the meat in quantities harmful to man. The Food and Drug Administration is responsible for approving the use of drugs in meat animal rations and establishing the tolerances, or the maximum quantity of a chemical that can be present in food. To avoid contamination of the meat, some drugs must be withdrawn from the ration prior to slaughter. Therefore, it is important that producers follow the directions stated on the package of all drugs used. Tables 14 and 15 list the recommended levels for feed additives in swine rations.

Copper compounds have growth-stimulating value equal to antibiotics. They are also effective as a therapeutic treatment for intestinal disorders that do not respond satisfactorily to antibiotics or arsenicals. Copper is toxic when fed in excessive amounts (250 parts per million or more) for prolonged periods. Copper compounds should not be added to hog rations if a lagoon manure disposal system is being used. The copper will seriously interfere with the bacterial action in the lagoon.

Table 13. Approximate daily water consumption as affected by season.

Weight of pig pounds	Spring pounds	Fall pounds
25	3.3	2.5
50	5.5	4.5
75	8.5	7.0
100	9.0	7.5
150	10.0	9.0
200	9.0	9.6
250	7.5	7.5

(Source of data – Swine Production by Krider and Carroll.)

Table 14. Recommended antibiotic and arsenical levels.

	Grams per ton of complete feed		
Ration	Antibiotic	Arsanilic acid[a]	3-Nitro[a]
Creep	40	90	22
Grower	10 to 20	90	22
Finisher	10	90	22
Therapeutic	100 to 200	90	22
Supplement	50 to 100	450	100

[a] *Never use both arsenicals in a single ration at the levels indicated.*

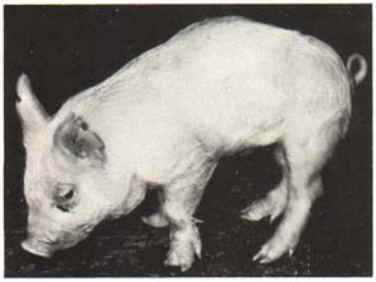

Figure 6. — Calcium-deficient pig with advanced rickets. Pig was scarcely able to walk. Back becomes arched and eyes protrude because soft tissue growth has outdistanced skeletal growth.

There are numerous drugs on the market which can be used alone or in combination for the promotion of growth and the control of swine diseases. The use of feed additives for the prevention and treatment of swine diseases is covered in MSU Ag Facts No. 51, "Swine Disease Guide."

Table 15. Recommended levels of copper compounds for growing-finishing swine[a].

Copper compound	Percent of copper	Grams per ton
Cupric carbonate ($CuCO_3$)	51	222
Cupric oxide (CuO)	80	142
Cupric sulfate ($CuSO_4.5H_2O$)	25	454

[a] Amount to add per ton of complete ration to furnish 125 parts per million of copper.

Ration Formulation

A swine producer has four alternatives when it comes to developing his hog feeding program. He can (1) purchase a commercial protein supplement to mix with his home grown grains, (2) purchase soybean meal, minerals, and a vitamin-trace mineral premix to add to home grown grains, (3) purchase a complete feed, or (4) buy individual nutrients and build a complete ration. All methods can be equally successful. The system chosen will depend on his knowledge of nutrition, volume of feed required and the availability of capital to establish a feed processing and storage center.

Most producers rely on local elevators and commercial feed companies to supply their feed needs in one form or another. Elevators usually extend credit and offer personalized services. Large operations have the advantage of buying in sufficient quantities to demand discount prices while small producers pay the high feed dollar.

Many producers who have made the investment in a feed processing center and elected to formulate their own rations have found that they have been able to reduce feed costs materially. They like the idea of knowing exactly what they are feeding and the freedom to schedule and make changes as desired. This is particularly advantageous in the case of medications.

Home formulation is not without problems and disadvantages. The items listed below may help in making the right decision.

Factors To Consider Before Starting A Home-Mixing Program

1. Some nutritional knowledge is essential if any formulation decisions are to be made. There must also be time to study, interpret and plan.
2. The operation must be large enough to justify the investment of capital to save labor and improve efficiency. Recent estimates place the minimum feed volume between 150 and 200 tons annually. This amount is needed for the output of 20 to 25 sows on a 2-litter program.
3. Equipment needs include a grinder-mixer, storage bins, small mixer, scales, augers, etc.
4. Fixed investments mean some loss of flexibility. Investment in feed processing equipment is a commitment to stay in the livestock business, for only by steady use over a period of time can the investment be recovered.
5. Feed costs should include labor, depreciation, taxes, insurance, and interest on investment as well as ingredient costs.
6. There must be a readily available supply of ingredients (soybean meal, premixes, vitamins, antibiotics, drugs, etc.) at a fair price. Bulk buying in volume at discount prices is essential to the success of a home-mixing program.
7. Inventory, quality control, and nutrient storage losses may cause problems and increase costs. Storage time should not exceed 3 to 6 months.
8. When all factors are considered, unless the ingredients which go to make up a protein supplement can be purchased for about $20.00 cheaper than a good commercially prepared supplement,

there will be little advantage in a home-mixing program. This should leave enough to cover interest on investment, taxes, labor, and other overhead costs.

To formulate a ration accurately, a producer should become familiar with the metric system of measurement. Many nutrients such as vitamins and trace-minerals are required in the ration in quantities of less than a pound per ton. The metric system provides units which permit small quantities to be broken down into fractions of a pound. Weight conversions are shown in Table 16.

A nutritional term having common usage is "International Unit" (I.U.). This term refers to the quantity of a biological compound (such as a vitamin) that produces a particular biological effect agreed upon as an international standard. International units are used to designate the activity of vitamins A, D and E.

MSU System of Formulation

The Michigan State University system of swine formulation involves the use of (1) a vitamin-trace mineral and selenium premix, (2) a fortified swine supplement, and (3) farm-grown grains. These three are combined to make two rations — MSU 16 (16 percent protein) and MSU 13 (13 percent protein) — that will meet the needs of all swine after they weigh 30 pounds.

The Michigan State University Vitamin-Trace Mineral Premix (Table 17) has purposely been overfortified so that one premix can suffice for all ages of swine. The quantity of vitamins that are commonly

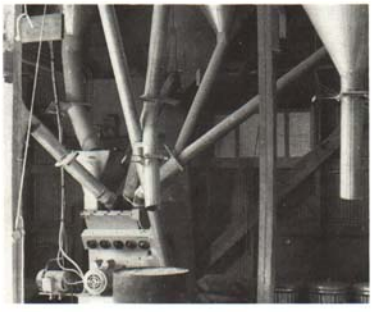

Figure 7.— This kind of grinding, metering, and mixing equipment requires a sizable volume to be economical.

Table 16. Commonly used weight conversions.

1 pound (lb.)	=	453.6	grams (gm.)
1 ounce (oz.)	=	28.35	grams
1 kilogram (kg.)	=	1,000	grams
1 gram	=	1,000	milligrams (mg.)
1 milligram	=	1,000	micrograms (mcg.)
1 mg. per lb.	=	2	gm. per ton
1 mcg. per lb.	=	2	mg. per ton
1 mg. per lb.	=	2.2	parts per million (p.p.m.)
.01 percent	=	90.8	gm. per ton

Table 17. Michigan State University vitamin-trace mineral premix.

Nutrient	Amount in 10 lb. of premix
Vitamin A	3.0 million IU
Vitamin D	0.6 million IU
Vitamin E	5 thousand IU
Vitamin K compound	2.0 g
Riboflavin	3.0 g
Nicotinic acid	16.0 g
D-pantothenic acid	12.0 g
Choline	100.0 g
Vitamin B_{12}	18.0 mg
Zinc	68.0 g
Manganese	34.0 g
Iodine	2.5 g
Copper	9.0 g
Iron	54.0 g
Antioxidant	45.0 g
Carrier (ground yellow corn)	To bring total to 10 lb

Suggested ingredients: Viatmin A palmitate in gelatin; stabilized Vitamin D_2 or D_3; stabilized Vitamin E (D- or D, L-alpha-tocopheryl acetate); menadione sodium bisulfite; riboflavin; nicotinic acid or nicotinamide; calcium pantothenate; choline chloride; vitamin B_{12} supplement; zinc carbonate, sulfate or oxide; manganous carbonate, sulfate or oxide; pentacalcium orthoperiodate or calcium iodate; copper sulfate, carbonate, hydroxide or oxide; ferrous sulfate or fumarate; butylated hydroxyanisole and/or butylated hydroxytoluene.

Table 18. Selenium premix.

Nutrient	Amount in 1 lb. of premix
Selenium	90.8 mg

Suggested ingredients: sodium selenite, carrier (calcium carbonate, soybean mill feed).

present in the basal feeds has been disregarded because of the uncertain amounts that may be present.

The swine producer should plan to purchase the vitamin-trace mineral premix (Table 17) and the selenium premix (Table 18) already mixed from a commercial supplier. A number of brokers or companies are prepared to market such premixes, manufactured to the customer's specifications, for less cost than they can be prepared by the farmer. No

more than 3 to 6 months' supply should be purchased at one time, and the premixes should be stored in a cool, dry place.

The Michigan State University Swine Supplement (Table 19) is designed for those farmers who have an automatically controlled grinder-mixer with a proportioning device. If a batch mill is used, these ingredients may be added individually to the ground corn and soybean meal required to make MSU 13 and MSU 16 percent complete feeds (Table 20).

Michigan State University 16 percent ration — can be used for the following classes of swine:

Lactating sows and gilts
Boars
Pigs nursing the sow
Growing pigs 30 to 125 pounds

Michigan State University 13 percent ration — can be used for:

Replacement gilts — 200 pounds to breeding
Bred sows and gilts
Finishing pigs — 125 pounds to market.

Table 19. Michigan State University swine supplement.

Ingredient	Amount
Salt	10 lb.
Limestone (38% calcium)	20 lb.
Dicalcium phosphate	20 lb.[a]
MSU vitamin-trace mineral premix	10 lb.
Selenium premix	1 lb.
Carrier - ground yellow corn	39 lb.
	100 lb.

[a] When formulating MSU 13 to be limit-fed to sows and gilts during gestation, increase dicalcium phosphate to 30 lb. and reduce carrier to 29 lb.

NOTE: The addition of two pounds of fat in place of a like amount of corn will reduce dustiness and may prevent some separation. Antibiotics and/or other feed additives should be included in the above supplement as warranted by individual farm conditions.

Table 20. Michigan State University "16 percent" and Michigan State University "13 percent" complete feeds.

Ingredient	MSU 16	MSU 13
Corn	1470 lb.	1640 lb.
Soybean meal (44%)	430 lb.[a]	260 lb.[a]
MSU Supplement	100 lb.	100 lb.
	2,000 lb.	2,000 lb.

[a] 49 percent soybean meal can be substituted for the 44 percent meal by reducing the amounts to 380 and 230, respectively, and replacing the difference with corn.

Determining The Proportion of Corn-To-Protein Supplement To Use In Rations

Below is a simple method of determining how much grain and how much protein supplement to use to make a mixture with a certain protein content. In this example, a mixture containing 16 percent protein is to be made from corn containing approximately 9 percent protein and supplement containing 40 percent protein.

Draw a square. In the center of the square, put the protein content desired in the final mixture.

At the upper left-hand corner of the square, write "corn" and its protein content (9); at the lower lefthand corner, write "supplement" and its protein content (40).

Subtract diagonally across the square (the smaller from the larger), and enter the results at the corners on right-hand side (16 − 9 = 7; 40 − 16 = 24).

The number at the upper right-hand corner gives the parts of corn, and the number at the lower right-hand corner, the parts of supplement needed to make a mixture with 16 percent protein.

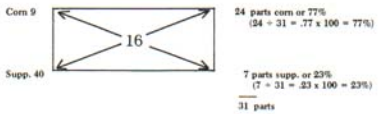

Figure 8. Determining the proportion of corn to protein supplement.

Therefore, a mixture of 77 pounds of corn and 23 pounds of protein supplement would make a ration containing 16 percent protein.

Table 21. Calculating the protein content of a ration.

Ingredient		Protein in feed
1,524 lb. ground corn	times 0.09 =	137.16
150 lb. soybean meal	times 0.44 =	66.00 lb.
100 lb. meat and bone meal	times 0.50 =	50.00 lb.
200 lb. alfalfa meal	times 0.17 =	34.00 lb.
6 lb. dicalcium phosphate		
10 lb. salt		
10 lb. vitamin-trace mineral premix		
2,000 lb.		287.16 lb.

287.16 ÷ 2,000 = 0.143 x 100 = 14.3% protein

Feeding The Sow Herd

Pre-Breeding and Breeding Season

Gilts retained for breeding purposes should be removed from the feedlot at 175 to 200 pounds (5 months of age) and hand-fed a 13 percent ration (MSU 13) until they are 7.5 months of age. Usually 4 to 5 pounds of feed per day will keep them in a good growing condition. If on good pasture, this amount can be cut to 3 to 4 pounds.

At 7.5 months of age, increase the daily quantity of feed to 6 or 7 pounds and turn in the boar 3 to 7 days later. Remove the gilts from the breeding pen when it is evident that they have been serviced and limit the daily feed intake to levels listed below.

Hand-Feeding Sow and Gilts During Gestation

The feeding of brood sows and gilts during gestation offers a great potential for feed saving. Sows and gilts kept in a thin to medium condition farrow just as many or more pigs than sows permitted to become fat. They also have fewer problems at farrowing time. The amount of feed listed below should be used as a guide, but the actual day-by-day feeding will depend on the condition of the sows. The caretaker must make the necessary adjustments. Once-per-day feeding is just as good as twice-per day feeding.

Amount To Feed During Gestation

	On Pasture	*In Dry Lot*
Gilts	4 pounds	5 pounds
Sows	3 pounds	4 pounds

MSU 13 listed in Table 20 or any of the rations listed in Table 22 can be hand fed. Some farmers prefer to hand-feed corn and protein supplement, rather than feed a mixed ration. When this method of feeding is used, it is preferable to feed one ingredient at night and the other in the morning. If both

Table 22. Sow gestation rations.

	Ration number											
Ingredient	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Corn	1735			1352		1566	1394	1574	1755	1802	1678	1887
Opaque-2 corn		1843										
Sorghum grain			1705									
Oats				400								
Wheat					1781							
Wheat bran						200						
Wheat middlings							400					
Alfalfa meal								200				
Meat and bone meal									100			
Tankage										100		
Soybeans, heated											260	
Lysine, 78%L-												5
Soybean meal (44)	202	93	235	186	157	177	147	170	110	55		43
Limestone	23	22	22	23	25	27	30	16	14	16	23	22
Dicalcium phosphate	24	26	22	23	21	14	13	24	5	11	23	27
Salt	5	5	5	5	5	5	5	5	5	5	5	5
Selenium premix	1	1	1	1	1	1	1	1	1	1	1	1
MSU VTM premix	10	10	10	10	10	10	10	10	10	10	10	10
	2000	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**
Analyses												
DE,kcal/lb	1565	1570	1560	1495	1570	1520	1515	1470	1550	1560	1625	1575
Protein, %	12.2	12.2	13.8	12.5	13.3	12.4	12.5	12.4	12.7	12.1	12.3	9.3
Lysine, %	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
Methionine +cystine, %	.43	.38	.37	.42	.42	.44	.42	.42	.42	.40	.41	.36
Tryptophan, %	.12	.14	.15	.13	.16	.13	.13	.15	.11	.11	.12	.08
Ca, %	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
P, %	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50

ingredients are fed at the same time, the timid sows are often fought away from the supplement and consume mostly corn. Feeding stalls help to solve this problem.

Regulate the quantity of corn fed to keep the animals in medium condition. Gilts should receive one pound of a 40-percent protein supplement daily, and sows two-thirds of a pound, to meet their protein requirement. A satisfactory protein supplement is listed in Table 33.

Sows and gilts can be used to glean corn fields in the fall, but it is difficult to prevent them from becoming over-fat. It is usually wise to let finishing hogs clean up most of the corn before turning in the sow herd. When this is not possible, corn intake can be curtailed by allowing the sows access to the corn field every third day.

Self-Feeding During Gestation

There are two ways of self-feeding during gestation. The most common method is to self-feed the sows a bulky ration. This method gives satisfactory sow performance, but grinding costs and excessive feed intake make it expensive. When justified because of a labor situation, the following ration can be fed:

Table 23. Bulky ration for self-feeding during gestation.

Ingredient	Amount
Ground shelled corn	599 lb.
Ground oats	600 lb.
Ground alfalfa hay or alfalfa meal	600 lb.
Soybean meal (44%)	120 lb.
Meat and bone meal	60 lb.
Salt	10 lb.
MSU vitamin-trace mineral premix	10 lb.
Selenium premix	1 lb.
	2,000 lb.

If sows have a tendency to become over-fat, substitute ground ear corn for the ground shelled corn.

A second method of self-feeding sows is to feed a high-energy ration (MSU 13), but limit the access to the self-feeder. Sows are simply shut away from the feeder for 2 days out of 3. This method has proven to be quite satisfactory in regulating feed intake, and the performance has been as good as hand feeding 4 pounds of feed every day.

Silage Feeding During Gestation

Corn silage is available on many dairy and beef farms and makes an excellent feed for brood sows. However, unless the sow herd is extremely large, it would not pay to construct a silo if there are no other silage-consuming livestock on the farm.

Silage serves as a substitute for pasture and alfalfa meal. It should be fed fresh daily in amounts the sows will clean up in 2 to 3 hours. Sows will usually eat 10 to 15 pounds, and gilts, 8 to 12 pounds. Some wastage can be expected. It is important that the silage be supplemented with 1.0 to 1.5 pounds of a good protein supplement per head daily. Feed additional corn, if necessary, to keep sows in proper condition. The following precautions should be noted.

1. Never feed silage alone or a poor pig crop will result.
2. Silage causes digestive upsets (diarrhea) in baby pigs. Do not feed it to lactating sows.
3. Avoid feeding moldy silage. It can cause sows to abort.

Antibiotics in Brood Sow Rations

Experimental results have been somewhat inconclusive regarding the value of antibiotics in brood sow rations. Breeding herds having a high disease level may show a favorable response.

Before investing a considerable sum in antibiotics, it is wise to have a sensitivity test run to determine which antibiotics are effective against the organism present. Veterinarians are equipped to take vaginal smears which can be cultured in the state diagnostic laboratory.

Pasture For Brood Sows

Good legume pasture is an excellent feed for brood sows but it is not indispensable. The decision of whether to feed on pasture or in dry lot will depend on whether the land can be put to a more profitable alternative use.

Research data support the conclusion that three pounds of feed per head daily on pasture provides a gain of sows and gilts during pregnancy equal to four pounds per head daily in dry lot. On this basis, it has been calculated that one acre of alfalfa pasture has a feed-replacement value of approximately 1,000 pounds (about $50) when stocked at the rate of 10 animals per acre.

Land not suitable for a continuous cropping program is often available on farms. Under these cir-

cumstances, a forage crop can be utilized to advantage by brood sows. The farrowing and weaning records are about the same for sows and gilts fed in drylot as compared to those fed during gestation on legume pasture.

Alfalfa Meal For Brood Sows

The favorable results obtained from feeding a corn-soybean meal ration, properly fortified with vitamins and minerals, has caused researchers to question the importance of alfalfa meal in the gestation ration. Alfalfa meal will supply nutrients such as vitamins, protein, and calcium, but these can usually be purchased more cheaply from other sources. Until it has been definitely proven that alfalfa meal contains some unknown nutrient essential for improved reproductive performance, it is questionable whether it should be included in the ration.

Ground alfalfa hay is a good source of bulk in a self-fed gestation ration.

Feeding Sows At Farrowing Time

Move the sow to the farrowing house four or five days prior to farrowing. Hand-feed three to four pounds of the regular gestation ration mixed with one to two pounds of wheat bran. This makes the ration more bulky and has a laxative effect.

Feeding Lactating Sows

Do not feed the sow the day she farrows. Starting the second day, feed three or four pounds per day of MSU 16 and gradually increase the amount until she is on full feed when the litter is 7 to 10 days old. A sow will eat about 12 pounds per day when on full feed. For maximum milk production, do not add bulky, high-fibrous feeds, such as alfalfa meal, to the lactation ration.

MSU 16 listed in Table 20 or any of the rations listed in Table 24 make a satisfactory ration for lactating sows.

Table 24. Sow lactation rations.

	Ration number											
Ingredient	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Corn	1579			1200		1409	1244	1424	1605	1661	1478	1711
Opaque-2 corn		1678										
Sorghum grain			1550									
Oats				400								
Wheat					1612							
Wheat bran						200						
Wheat middlings							400					
Alfalfa meal								200				
Meat and bone meal									120			
Tankage										120		
Soybeans, heated											462	
Lysine, 78%L-												5
Soybean meal (44)	360	260	390	340	327	334	300	322	248	182		222
Limestone	24	24	23	24	24	29	30	16	12	15	25	23
Dicalcium phosphate	21	22	21	20	21	12	10	22	0	6	19	23
Salt	5	5	5	5	5	5	5	5	5	5	5	5
Selenium premix	1	1	1	1	1	1	1	1	1	1	1	1
MSU VTM premix	10	10	10	10	10	10	10	10	10	10	10	10
	2000	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**
Analyses												
DE,kcal/lb	1560	1565	1505	1500	1560	1505	1505	1465	1540	1550	1660	1560
Protein, %	15.0	15.0	16.5	15.3	16.2	15.2	15.3	15.2	15.6	15.1	15.1	12.5
Lysine, %	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.72
Meth. + cystine, %	.51	.46	.44	.50	.49	.52	.49	.50	.49	.47	.46	.44
Tryptophan, %	.17	.18	.19	.18	.20	.18	.18	.19	.15	.15	.17	.13
Ca, %	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
P, %	.50	.50	.50	.50	.50	.50	.50	.50	.52	.50	.50	.50

Creep Feeding Baby Pigs

The trend is towards early weaning of pigs at three to five weeks of age so sows can be rebred to maximize production. For satisfactory performance of pigs weaned at this young age environmental factors are as important as proper nutrition. Optimum temperature for slotted floor facilities is 85°F and 75°F for solid floors with bedding. Provide sufficient ventilation to control the humidity and keep the building dry and free of drafts.

Rarely will pigs eat any quantity of creep ration before they are three weeks of age. This is especially true if the sow is a heavy-milker. Pigs can be encouraged to eat by placing a small handful of creep feed in a shallow pan or on the floor in the sleeping area. Replace with fresh feed each day until the pigs learn to eat. It should be remembered that pigs will consume more creep ration and gain faster if they have free access to fresh water.

Creep or starter rations, which should give satisfactory performance, are listed in Table 25.

Figure 9. — Profits start with the brood sow at farrowing time. Each pig lost is like throwing away a $10.00 bill.

Feeding from Weaning to Market

Free-Choice vs. Mixed Rations

In designing the feeding program, each producer must decide whether free-choice feeding or mixed rations best fit the size and intensity of his particular operation. From a nutritional standpoint, neither

Table 25. Recommended starter rations (15 to 30 pounds)

Ingredient	MSU starter	Corn-soy + syn.A.A.[d]	Hi-lysine corn	20% Dried whey prod.
Ground shelled corn	989	1480	—	1204
High lysine corn	—	—	1484	—
Soybean meal (44%)[a]	440	440	440	350
Rolled dehulled oats	200	—	—	—
Dried skimmilk	200	—	—	—
Sucrose	100	—	—	—
Ground limestone	20	20	20	10
Dicalcium phosphate	16	30	30	20
Salt	10	10	10	—
MSU VTM premix[b]	20	10	10	10
Selenium premix[b]	1	1	1	1
Antibiotic premix[c]	5	5	5	5
Lysine (78%)	—	4	—	—
Dried whey product (17%)	—	—	—	400
	2000	2000	2000	2000
Analyses				
DE,kcal/lb	1500	1550	1550	1550
Crude protein, %	19.5	16.6	17.4	16.4
Ca, %	0.76	0.81	0.81	0.79
P, %	0.55	0.59	0.59	0.60
Lysine, %	1.02	0.96	0.94	0.94
Methionine + cystine, %	0.67	0.59	0.55	0.63
Tryptophan, %	0.24	0.18	0.22	0.21

[a] *When using soybean meal 49, use 10% less and replace the difference with an equal amount of corn.*
[b] *Vitamin-trace mineral premix as in Table 17. Selenium premix as in Table 18.*
[c] *May be Aureo-SP250, tylosin (50 g), arsanilic acid (90 g) or copper (250 ppm), etc.*
[d] *Corn-soybean meal ration plus synthetic amino acids.*

program has shown consistent advantage over the other. The same can be said of feed cost when all factors such as labor, grinding, and mixing are included. However, ground mixed rations do have the following advantages:

1. More uniform performance can be expected. There are fewer "tail-enders" at market time. Thus, the use of facilities can be kept on schedule.

2. Protein supplement consumption is easier to control. Under free-choice feeding, the supplement consumption is markedly influenced by its palatability. Pigs will over-eat on soybean meal when it is fed as a single protein ingredient. *Rule of Thumb:* If pigs eat *more* than ¾ to 1 pound of supplement per head per day from 40 pounds to market weight, they are eating more than is required to meet their protein needs.

3. When on pasture, hogs of all weights usually gain faster on a mixed ration. The advantage does not seem to be so great in drylot.

Restricted Feeding

Construction of swine housing having partial slotted floors and long, narrow pens has created an interest in restricted feeding. Feed is dropped directly on the floor at frequent time intervals. Unless the quantity of feed dropped is restricted to what the pigs will clean up in 15 to 20 minutes, considerable feed wastage is encountered. Restricted feeding should not be practiced until pigs weigh at least 100 pounds.

When hogs are fed by this method, as compared to self-feeding, the following results can be expected:

1. Restricting feed intake reduces daily gain on the average .15 to .20 pounds with each 10 percent restriction. This decreased growth rate results in an increased feeding time of 7 to 10 days to reach market weight with each 10 percent restriction.

2. The optimum level of feed restriction appears to be 75 to 80 percent of full feed. Restriction beyond this level increases the feed required per pound of gain.

3. Restricted feed intake improves carcass quality. The carcasses have less backfat and a higher yield of preferred lean cuts.

Preparation Of Feeds

Fineness of Grind

Fine to medium grinding of corn improves feed efficiency, as compared to coarsely ground or shelled corn. This is particularly true in the case of hogs over 100 pounds in weight. Fine grinding will cause some bridging in self feeders.

Feed grains with a considerable amount of hull, such as oats and barley, should be finely ground.

Pelleting Feeds

Pelleting of corn-soybean meal rations improves the efficiency of gain under either full or restricted feeding. Part of the improvement in efficiency of gain is probably due to less feed wastage. Pigs will consume pelleted feed more rapidly than meal rations. Rations containing a considerable amount of fiber are improved by pelleting because of increased consumption, improved carbohydrate digestibility, and reduced sorting and wastage compared to meal rations.

Pelleting has resulted in an average of 7 or 8 percent greater gain per ton of feed consumed. From a feed cost standpoint, pelleting is justified when the cost of pelleting and handling a ton of feed is less than the value of 150 pounds of the feed.

Liquid Or Paste Feeding

Liquid or paste feeding will definitely cut down on feed wastage. In some cases it will increase feed consumption and improve rate of gain. Labor costs may be higher than self-feeding. When hogs are limit fed, there is a consistent advantage in wetting a complete ground mixed ration with 1.5 parts of water for each part of dry feed.

Effect of Heating on Feeding Value of Corn

Some chemical changes do occur when grains heat in storage or are subjected to artificial heat in drying. However, the changes due to heat are usually relatively small and the energy value remains surprisingly good. Considerable loss in carotene content can be expected. In most instances, other factors such as molds and fungi cause more damage to the grain than heating.

Various experiments have been run to determine the effect of artifically drying at low and high temperatures. The nutritive value of corn was not affected.

High-Moisture Corn

Ensiling high-moisture shelled corn does not improve the nutritional value of the corn. Therefore, the decision to feed high-moisture corn must be based on whether this type of harvesting and stor-

age is the most efficient handling method on a particular farm. A farmer is not justified in constructing a silo just in order to feed high-moisture corn.

Experimental results indicate that pigs fed high-moisture corn gained 2 percent faster, but required 7 percent more corn to produce 100 pounds of gain. Results were determined on a moisture equivalent basis. No difference was noted between corn stored in a regular silo or in air-tight storage. On a free-choice basis, pigs fed high-moisture corn utilized 4 percent less protein supplement and required 5.5 percent more total feed per unit of gain.

Feeding high-moisture corn is somewhat of a problem. It is usually very palatable and when fed free-choice, pigs will often over-eat on corn and under-eat on protein supplement. When the two are metered together, separation is likely to occur. Some producers grind the quantity of corn needed each day in order to mix it with protein supplement. This adds labor and extra cost.

High-moisture corn should be fed fresh daily to prevent spoilage and caking in feeders. In winter months it will often freeze in outside feeders. One inch or more must be taken off the top of a silo to prevent spoilage in warm weather.

Spoilage may be prevented by treating the high moisture corn at the time of harvest with up to 1% of propionic acid or a mixture of propionic and acetic acids. Acid treatment also eliminates the need for frequent grinding and mixing because mixed feeds made from acid-treated high moisture corn will store well for several days. A schedule of the amount of acid to use in relation to corn moisture is as follows:

Corn Moisture	Propionic Acid Required		
%	%	lb/ton	oz/bu
18	.4	8	3.5
22	.6	12	5
26	.8	16	7
30	1.0	20	9

High Lysine Corn

Since lysine is the first limiting amino acid in a corn-soybean meal ration, the amount of soybean meal which must be used in the ration is dependent upon the lysine analysis of the corn. Regular corn averages about .25 percent lysine with a range of .20 percent to .30 percent. High lysine corn ranges in analysis from .30 percent to .50 percent lysine with an average of about .40 percent. Because of the variation in lysine analysis of high lysine corn, it is best to have it analyzed before calculating and compounding rations.

A formula for calculating the percentages of high lysine corn and soybean meal (44 percent) in a grower ration is –

$$(l)\ C + (2.8)\ S = (L)\ 100$$

in which

l=% lysine in corn
2.8=% lysine in soybean meal (44 percent)
L=% lysine required in grower ration
C=% of corn in the ration
S=% of soybean meal (44 percent) in the ration

Determine l by chemical analysis of the corn for lysine. Suppose that the high lysine corn analyzes .40 percent lysine. The percent lysine required in the grower ration is found in Table 26. Thus, L = .75. Corn and soybean meal together make up 97 percent of the ration with 3 percent of the ration consisting of mineral, vitamin and antibiotic supplements. Thus, C + S = 97 and C = 97–S.

Now the formula can be written with only one unknown, that is –

$$\begin{aligned} (.40)\ (97-S) + 2.8(S) &= (.75)100 \\ 38.8 - .4S + 2.8S &= 75. \\ 2.8S - .4S &= 75 - 38.8 \\ 2.4S &= 36.2 \\ S &= 15 \\ C = 97 - S &= 97 - 15 = 82 \end{aligned}$$

Thus, the grower ration would consist of –

	%	lb. per ton
High lysine corn	82	1640
Soybean meal (44%)	15	300
Minerals, vitamins & antibiotics	3	60
	100	2000

Table 26 shows the percentages of corn and soybean meal (44 percent) or corn and soybean meal (49 percent) in grower and finisher rations with varying levels of lysine in corn.

The value of high lysine corn for feeding swine is related to its lysine value and the corresponding reduction in soybean meal needed to meet the lysine requirement. The price which a producer can pay for high lysine corn is thus dependent upon (1) the lysine analysis of the high lysine corn and the current prices of (2) regular corn and (3) soybean meal. The influence of these three factors upon the value of high lysine corn is shown in Table 27.

Table 26. Percentages of corn and soybean meal (SBM 44) or corn and soybean meal (SBM 49) in grower and finisher rations with varying levels of lysine in corn.[a]

% Lysine in corn	Grower rations (.75% lysine)				Finisher rations (.55% lysine)			
	Corn	SBM44	Corn	SBM49	Corn	SBM44	Corn	SBM49
.20	75.6	21.4	77.8	19.2	83.3	13.7	84.8	12.2
.25	77.1	19.9	79.2	17.8	84.9	12.1	86.2	10.8
.30	78.7	18.3	80.6	16.4	86.6	10.4	87.8	9.2
.35	80.3	16.7	82.1	14.9	88.4	8.6	89.4	7.6
.40	82.0	15.0	83.6	13.4	90.2	6.8	91.0	6.0
.45	83.7	13.3	85.2	11.8	92.2	4.8	92.7	4.3
.50	85.4	11.6	86.8	10.2	94.2	2.8	94.5	2.5

[a] *Assuming that corn and soybean meal constitute 97% of the ration and mineral, vitamin and antibiotic supplements the other 3%.*

Table 27. Value of high lysine corn of varying lysine analysis as influenced by the price of regular corn (.25% lysine) and soybean meal (SBM 44).

Price		Value of high lysine corn, $/bu.				
Regular corn, $/bu.	SBM 44 $/ton	% lysine in high lysine corn				
		.30	.35	.40	.45	.50
2.50	120	2.52	2.53	2.54	2.56	2.57
3.00	120	3.01	3.02	3.02	3.03	3.04
3.50	120	3.50	3.50	3.50	3.50	3.50
2.50	150	2.53	2.56	2.60	2.63	2.66
3.00	150	3.03	3.05	3.07	3.10	3.12
3.50	150	3.52	3.53	3.54	3.56	3.58
2.50	180	2.54	2.60	2.65	2.69	2.74
3.00	180	3.04	3.08	3.12	3.16	3.20
3.50	180	3.53	3.56	3.60	3.62	3.66
2.50	210	2.55	2.63	2.70	2.76	2.82
3.00	210	3.06	3.12	3.17	3.23	3.28
3.50	210	3.55	3.60	3.65	3.69	3.74

Computer Programming

When only grain and commercial supplement are considered as ration ingredients, it is a simple matter to calculate the proportions of these in any ration as illustrated in Fig. 8. Likewise, even when fortified grain-soybean meal rations are used the number of ration ingredients is small enough that these calculations can also readily be made by hand (Table 21). However, if many ingredients are to be considered in an effort to put together the required nutrients in a ration at the least cost, it becomes extremely difficult if not impossible without the use of a modern electronic computer.

The computer must have programmed information before it can give useful answers.The type of input data which need to be provided to the computer by linear programing as well as the output information which the computer will give back are shown in Fig. 10.

A computer model called Telplan 12 has been developed at Michigan State University for use in determining least cost rations. Table 28 gives the nutrient requirements and limitations for the various weights and classes of swine for which rations may be computed. Table 29 gives the nutrient composition of the ingredients considered by the computer as possible components of the ration as well as any limitation on the use of ingredients in specific rations. The other data which must be provided to the computer by the producer are the cost of each of the ingredients to be considered as possible components of the ration.

Accurate ingredient prices are mandatory.

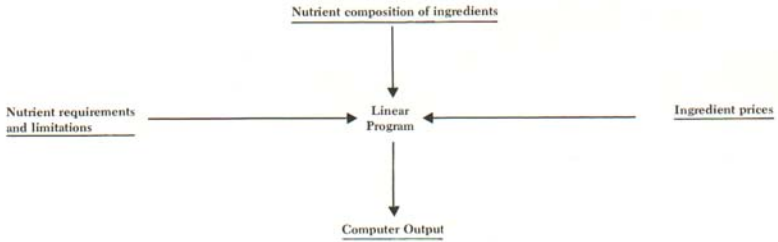

Fig. 10. Diagram of computer program showing input data and output information.

This means prices of ingredients at the time of programming, including delivery or storage costs to the point of actual ration manufacture. The output obtained from the program includes the least cost ration formula and its cost, the nutrient compositon of the ration, the break-even price at which an ingredient not in the ration would enter the ration and the price range where least cost ration ingredients would remain least cost. Output data are no more valid than the input data provided.

Least cost models are designed to minimize feed cost per pound assuming any combination of ingredients meeting the nutrient requirement specifications will result in the same rate and efficiency of gain. Least cost models do not consider the economic advantages if alternative specifications

Table 28. Nutrient requirements of swine (per pound of feed).

Nutrient[a]	Unit	Gestation[b]	Lactation	Growing-finishing rations for pigs weighing— 10-25	25-50	50-75	75-125	125-220
Energy[c]								
Digestible, min.	kcal/lb.	1530	1530	1570	1550	1530	1510	1490
Amino Acids								
Lysine, min.,	Pct.	0.50	0.70	1.20	0.95	0.75	0.65[d]	0.55[d]
Methionine + cystine, min.	Pct.	0.30	0.30	0.70	0.60	0.50	0.40	0.30
Tryptophan, min.	Pct.	0.08	0.13	0.18	0.15	0.13	0.11	0.09
Minerals								
Calcium, min.	Pct.	0.75	0.75	0.8	0.6	0.5	0.5	0.5
max.	Pct.	0.95	0.95	1.1	0.8	0.7	0.7	0.7
Phosphorus, min.	Pct.	0.50	0.50	0.8	0.6	0.5	0.5	0.5
Salt, min.	Pct.	0.25	0.25	0.25	0.25	0.25	0.25	0.25

[a] *Vitamins and trace minerals should be supplied to meet National Research Council Requirements.*
[b] *Gestation ration requirements based on 4 to 5 pounds feed per sow per day.*
[c] *The energy levels are set, for the growing and finishing pig, at levels which assure maximum daily gains. If energy per pound of feed drops below the levels specified, daily energy intake will be depressed and, consequently, daily gains will fall. If energy per pound of feed exceeds the minimum, daily gains typically will not improve; however, gain per pound of feed typically improves.*
[d] *Higher lysine levels may be warranted for meaty pigs (loin eyes exceeding 5 sq. in. @ 220 lbs.) and/or for high grain prices relative to protein prices.*

Table 29. Feed ingredients.

Feed specification code	1	2	3	4	5	6	7	8	9	10	11	12	13
Feed	Digestible energy	Crude protein	Crude fiber	Calcium	Phosphorus	Salt	Lysine	Methionine + cystine	Tryptophan	Maximum % of feed in ration 25-50	50-75	75-125	125-mkt.
No. Description	kcal/lb.	%	%	%	%	%	%	%	%	%	%	%	%
Energy Feeds													
1. Barley	1500	11.0	7.0	.05	.30	—	.35	.40	.15	40	60	60	80
2. Corn	1630	8.8	2.5	.02	.26	—	.25	.35	.07	NL	NL	NL	NL
3. High lysine corn (1)	1630	11.0	2.5	.02	.26	—	.40	.35	.12	NL	NL	NL	NL
4. Sorghum grain	1550	10.0	2.7	.05	.27	—	.20	.25	.09	NL	NL	NL	NL
5. Oats	1320	12.0	12.0	.08	.32	—	.35	.35	.15	20	30	30	40
6. Spelt (Emmer)	1320	12.0	10.0	.08	.33	—	.27	.35	.09	20	30	30	40
7. Rye	1560	11.3	2.0	.07	.34	—	.45	.32	.12	20	20	20	25
8. Molasses, beet	1120	6.0	0.0	.12	.03	—	—	—	—	5	5	5	5
9. Molasses, cane	1150	2.9	0.0	.81	.08	—	—	—	—	5	5	5	5
10. Wheat	1630	11.0	2.3	.05	.30	—	.30	.35	.12	NL	NL	NL	NL
11. Wheat middlings, standard	1450	15.5	7.0	.06	.80	—	.60	.40	.20	NL	NL	NL	NL
12. High lysine corn (2)	1630	9.8	2.5	.02	.26	—	.35	.35	.10	NL	NL	NL	NL
13. Triticale	1550	11.0	2.1	.06	.32	—	.45	.35	.11	50	50	50	50
14. Tallow	3600	—	—	—	—	—	—	—	—	5	4	4	3
Protein Feeds													
20. Commercial protein sup.										NL	NL	NL	NL
21. Alfalfa meal, dehydra. 17%	650	17	25.0	1.3	.24	—	.72	.40	.40	5	5	5	5
22. Blood meal	1220	80	1.0	.28	.22	—	6.0	2.30	1.00	3	3	3	3
23. Corn gluten meal, 41%	1600	42	4.0	.16	.40	—	.8	1.6	.20	NL	NL	NL	NL
24. Corn gluten meal, 60%	1600	60	2.5	.16	.50	—	1.0	3.0	.30	NL	NL	NL	NL
25. Corn gluten feed, 22%	1100	22	9.0	.30	.70	—	.6	.9	.12	NL	NL	NL	NL
26. Fish meal, menhaden	1400	60	1.0	4.00	3.00	—	4.8	2.2	.60	NL	NL	NL	NL
27. Meat and bone meal	1000	50	3.8	8.00	4.00	—	2.6	.9	.25	10	6	6	3
28. Soybean meal, 44%	1500	45	7.0	.25	.60	—	2.8	1.3	.63	NL	NL	NL	NL
29. Soybean meal, 49%	1550	49	3.0	.25	.65	—	3.1	1.4	.64	NL	NL	NL	NL
30. Tankage, meat meal	1220	60	2.0	6.00	3.00	—	4.0	1.1	.60	10	6	6	3
31. Whey, dried	1550	14	0.0	.90	.70	—	.7	.4	.15	10	10	10	10
32. Whey product, dried	1320	17	0.0	1.50	1.00	—	1.2	1.14	.36	20	20	20	20
33. Lysine										NL	NL	NL	NL
34. Methionine										NL	NL	NL	NL
35. Tryptophan										NL	NL	NL	NL
36. Full fat soybeans	1900	37.5	4.5	.20	.58	—	2.23	.90	.52	NL	NL	NL	NL

NL means there is no upper limit placed on the percentage of the feed that can occur in the least-cost ration. Of course, no feed will be in the ration at 100%; corn, for example, supplies adequate energy to meet the requirements but insufficient protein, calcium, phosphorus and salt.

(Continued page 28)

Table 29. Feed Ingredients (continued from page 27).

Feed specification code	1	2	3	4	5	6	7	8	9	10	11	12	13
Feed	Digestible energy	Crude protein	Crude fiber	Calcium	Phosphorus	Salt	Lysine	Methionine + cystine	Tryptophan	Maximum % of feed in ration 25-50	50-75	75-125	125-mkt.
No. Description	kcal/lb.	%	%	%	%	%	%	%	%	%	%	%	%
Minerals													
50. Commercial mineral sup.										NL	NL	NL	NL
51. Bone meal, steamed	300	—	—	26	13	—	—	—	—	NL	NL	NL	NL
52. Limestone, ground 37%	—	—	—	37	—	—	—	—	—	NL	NL	NL	NL
53. Phosphate, deflour.	—	—	—	32	18	—	—	—	—	NL	NL	NL	NL
54. Phosphate, dical.	—	—	—	24	18	—	—	—	—	NL	NL	NL	NL
55. Phosphate, monocal.	—	—	—	21	21	—	—	—	—	NL	NL	NL	NL
56. Phosphate, mono-& dical.	—	—	—	18	21	—	—	—	—	NL	NL	NL	NL
57. Salt	—	—	—	—	—	100	—	—	—	.25	.25	.25	.25
Protein, Mineral													
70. Commercial supplement										NL	NL	NL	NL

NL means there is no upper limit placed on the percentage of the feed that can occur in the least-cost ration. Of course, no feed will be in the ration at 100%; corn, for example, supplies adequate energy to meet the requirements but insufficient protein, calcium, phosphorus and salt.

were allowed in the program model. For example, if the cost of corn were high relative to the cost of protein, as in 1974, it might be economical to use a higher level of lysine since improved feed efficiency and economy of gain should result.On the other hand, when the cost of protein is extremely high relative to the cost of corn, as in 1973, it may be profitable to use a lower level of lysine in the specifications. Thus, the computer model can be extended to formulate rations designed to maximize profit per day rather than minimize cost per pound of feed.

Probably the most important factor limiting the use of the computer model by the individual swine producer is the limited number of ingredients that he is able to buy and store economically. Thus, the greatest use of computer models is by feed manufacturers and by producers with very large herds.

Growing and finishing rations which meet the nutrient specifications and ingredient limitations of the computer program are shown in Table 30 (30 to 75 pound pigs), Table 31 (75 to 125 pound pigs) and Table 32 (125 to 220 pound pigs).

Free-Choice Protein Supplement

Farmers desiring to prepare a protein supplement to be fed free-choice with home-grown grains for growing - finishing hogs can refer to Table 33. The supplement can also be mixed with grain to prepare complete mixed feeds. The quantity of supplement A to use in formulating a ton of various swine rations is listed below.

Type of Ration	Supplement A (pounds)	Corn (pounds)
Gestation	280	1720
Lactation	480	1520
Weaning to 125 lbs.	480	1520
125 lbs. to market	280	1720

Sex Differences

When full-fed, boars consume less daily feed than barrows or gilts, but are 10 to 15 percent more efficient in feed conversion. Boars also gain faster than barrows and gilts. Barrows gain approximately .10 pounds faster per day than gilts, which reduces their age at slaughter by 10 days. Feed per pound of gain is similar for barrows and gilts. Gilts yield carcasses having .11 inch less backfat, .52 square inches larger loin eye area, and 1.8 percent more lean cuts than barrows. Dressing percentage usually favors barrows, which is consistent with their greater depth of backfat.

Table 30. Grower rations for swine 30 to 75 pounds.

Ingredient	Ration number												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Corn	1507			1185	1142		1167	1620	1537	1633	1351	1440	1639
Opaque-2 corn		1600											
Sorghum grain			1458										
Oats				340									
Rye					400								
Wheat						1540							
Wheat middlings							400						
Fish meal								120					
Meat and bone meal									138				
Tankage										188			
Dried whey											200		
Soybeans, heated												400	
Lysine, 78%L-													5
Soybean meal (44)	437	342	488	420	403	406	382	222	306	160	400	125	300
Limestone	20	20	20	20	20	20	25	16	3	3	17	20	18
Dicalcium phos.	20	22	18	19	19	18	10	6	0	0	16	19	22
Salt	5	5	5	5	5	5	5	5	5	5	5	5	5
Selenium premix	1	1	1	1	1	1	1	1	1	1	1	1	1
MSU VTM premix	10	10	10	10	10	10	10	10	10	10	10	10	10
	2000	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**
Analyses													
DE,kcal/lb	1562	1567	1500	1500	1551	1566	1510	1578	1577	1570	1562	1665	1557
Protein, %	16.5	16.4	18.3	16.8	16.4	17.6	16.8	15.7	17.1	16.5	16.3	16.6	14.0
Lysine, %	.80	.80	.83	.80	.80	.80	.80	.80	.80	.80	.80	.80	.81
Meth. + cystine, %	.55	.54	.50	.54	.53	.54	.53	.56	.53	.51	.54	.51	.50
Tryptophan, %	.19	.20	.22	.20	.19	.22	.20	.17	.17	.17	.18	.19	.15
Ca, %	.67	.68	.66	.67	.67	.67	.65	.65	.65	.65	.65	.67	.65
P, %	.50	.50	.50	.50	.50	.50	.50	.50	.56	.54	.50	.50	.50

Table 31. Grower rations for swine 75 to 125 pounds.

Ingredient	Ration number												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Corn	1626			1126	1260		1285	1742	1654	1710	1472	1537	1789
Opaque-2 corn		1730											
Sorghum grain			1600										
Oats				522									
Rye					400								
Wheat						1655							
Wheat middlings							400						
Fish meal								120					
Meat and bone meal									120				
Tankage										120			
Dried whey											200		
Soybeans, heated												410	
Lysine, 78%L-													6
Soybean meal (44)	320	216	350	300	288	285	265	104	206	140	280		150
Limestone	16	14	14	16	16	16	22	10	4	7	14	17	14
Dicalcium phos.	22	24	20	20	20	18	12	8	0	7	18	20	25
Salt	5	5	5	5	5	5	5	5	5	5	5	5	5
Selenium premix	1	1	1	1	1	1	1	1	1	1	1	1	1
MSU VTM premix	10	10	10	10	10	10	10	10	10	10	10	10	10
	2000	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**
Analyses													
DE,kcal/lb.	1568	1574	1502	1466	1557	1572	1519	1585	1583	1575	1568	1647	1570
Protein, %	14.3	14.3	15.8	14.8	14.2	15.5	14.6	13.6	14.9	14.3	14.0	14.4	11.2
Lysine, %	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.67
Meth. + cystine, %	.49	.49	.43	.48	.47	.48	.48	.51	.48	.47	.48	.46	.41
Tryptophan, %	.16	.17	.18	.17	.16	.19	.16	.13	.14	.14	.15	.16	.11
Ca, %	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60
P, %	.50	.50	.50	.50	.50	.50	.50	.50	.51	.50	.50	.50	.50

Table 32. Finisher rations for swine 125 to 220 pounds.

Ingredient	Ration number												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Corn	1666			1044	1204		1325	1782	1677	1706	1512	1586	1821
Opaque-2 corn		1771											
Sorghum grain			1638										
Oats				648									
Rye					500								
Wheat						1703							
Wheat middlings							400						
Fish meal								120					
Meat and bone meal									60				
Tankage										60			
Dried whey											200		
Soybeans, heated												360	
Lysine, 78%L-													5
Soybean meal (44)	280	175	310	254	242	245	225	64	225	192	240		120
Limestone	16	14	14	16	16	16	22	10	12	10	14	16	14
Dicalcium phos.	22	24	22	22	22	20	12	8	10	16	18	22	25
Salts	5	5	5	5	5	5	5	5	5	5	5	5	5
Selenium premix	1	1	1	1	1	1	1	1	1	1	1	1	1
MSU VTM premix	10	10	10	10	10	10	10	10	10	10	10	10	10
	2000	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**
Analyses													
DE,kcal/ lb.	1570	1576	1503	1444	1556	1575	1520	1587	1578	1574	1571	1640	1573
Protein, %	13.6	13.7	15.2	13.9	13.6	14.9	13.9	12.9	13.9	13.6	13.2	13.7	10.7
Lysine, %	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60
Meth. + cystine, %	.47	.47	.41	.46	.45	.46	.46	.49	.47	.46	.46	.42	.40
Tryptophan, %	.15	.16	.17	.16	.15	.18	.15	.12	.14	.14	.14	.14	.10
Ca, %	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60
P, %	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50

Table 33. Free-choice protein supplement.

Ingredients	Supplement A
Soybean meal (44%)	1295
Meat and bone meal	350
Alfalfa meal	200
Limestone	60
Dicalcium phosphate	40
Trace mineral salt (Hi Zinc)	50
Selenium premix (Table 18)	5
	2,000
Crude protein, %	39.0
Calcium, %	3.77
Phosphorus, %	1.59

Recommended Vitamin Addition/T. Suppl. A	
Vitamin A (I.U.) millions	20
Vitamin D (I.U.) millions	2.7
Vitamin E (I.U.) thousands	30.0
Riboflavin (gm)	15.0
Pantothenic acid (gm)	50.0
Nicotinic acid (gm)	80.0
Choline (gm)	500.0
Vitamin B_{12} (mg)	70.0
Antibiotic (gm)	100.0

Table 34. Estimated corn and supplement requirements for swine.[a]

Life stage	Days	Daily feed lb.	Per sow per litter		Per pig raised		
			Corn[b] lb.	Suppl. lb.	Corn[b] lb.	Suppl. lb.	Creep lb.
Gilts to breeding age[c]							
Actual amount	75	5.0	(329)	(46)			
Amount required per sow replaced			82	12	10	2	
Breeding season	7	7.0	42	7	5	1	
Gestation	114	4.5	428	85	54	11	
Lactation	35	12.0	313	107	39	13	10
Starter (20 to 40 lb)	18	2.3			32	14	
Grower (40 to 125 lb)	56	4.5			189	63	
Finisher (125 to 220 lb)	56	7.0			327	65	
Boar (48 litters)		6.0	40	8	5	1	
Total			905	219	661	170	10

[a] *These amounts are based on 8 pigs raised per litter and 410 pounds of feed used in the entire swine operation per 100 pounds of market hogs produced.*
[b] *See Tables 2 and 3 to substitute other grains for corn.*
[c] *Amount of feed required for gilts to breeding age per sow replaced is ¼ the actual amount needed per gilt because it is assumed that sows farrow an average of 4 litters before being replaced.*

Partial List of Manufacturers and Suppliers of Feed Additives*

Vitamins A, D, E and K
Abbott Laboratories, N. Chicago, Ill.
Dawes Laboratories, Inc., Chicago, Ill.
Eastman Chemical Products, Inc., Kingsport, Tenn.
General Mills, Inc., Minneapolis, Minn.
Heterochemical Corp., Valley Stream, N.Y.
Hoffman-LaRoche, Nutley, N.J.
Merck & Co., Inc., Rahway, N. J.
Pfizer Inc., New York, N.Y.

B-Vitamins
Commercial Solvents Corp., Terre Haute, Ind.
Dawes Laboratories, Inc., Chicago, Ill.
Diamond Shamrock Chemical Co., Newark, N. J.
Merck & Co., Inc., Rahway, N. J.
Pfizer Inc., New York, N. Y.
Vitamins, Inc., Chicago, Ill.

Vitamin-Antibiotic-Trace Mineral Premixes
Dawes Laboratories, Inc., Chicago, Ill.
Henwood Feed Additives, Lewisburg, O.
Hoffman-Taff, Inc., Springfield, Mo.
Holt Products Co., Madison, Wisc.
Pfizer Inc., New York, N. Y.
Syntex Agri Business, Inc., W. Alexandria, O.
Thompson-Hayward Chemical Co., Kansas City, Kan.

Amino Acids
Ajinomoto, USA, Inc., New York, N. Y.
Dawes Laboratories, Inc., Chicago, Ill.
E. I. Dupont de Nemours Co., Inc., Wilmington, Del.
Merck & Co., Rahway, N. J.

Selenium Premixes
Calcium Carbonate Co., Quincy, Ill.
Dawes Laboratories, Inc., Chicago, Ill.
Micro Tracers Inc., San Francisco, Cal.

Antibiotics and Arsenicals
Abbott Laboratories, North Chicago, Ill.
American Cyanamid Co., Princeton, N. J.
Commercial Solvents Corp., Terre Haute, Ind.
Dawes Laboratories Inc., Chicago, Ill.
Elanco Products Co., Indianapolis, Ind.
Merck & Co., Inc., Rahway, N. J.
Penick, S. B. & Co., New York, N. Y.
Pfizer Inc., New York, N. Y.
Salsbury Laboratories, Charles City, Iowa
Smith Kline Animal Health Products, Philadelphia, Pa.

Sow Milk Replacers
Foremost Foods Co., San Francisco, Calif.
Land O' Lakes Inc., Fort Dodge, Iowa
Triple "F" Feeds, Des Moines, Iowa

**The above list is not complete; it is intended to indicate possible sources of certain feed additives. Some suppliers sell only to licensed feed manufacturers. Endorsement of any company or commercial products is neither intended nor implied.*