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Principles of Balancing Swine Diets

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A balanced swine diet contains the necessary nutrients in the correct proportions to nourish the animal properly. Required nutrients are energy, amino acids, minerals, and vitamins. Fat is required to supply essential fatty acids, but it is usually adequate in practical diets. Water is an important nutrient and normally is provided with free access, so it is not considered for diet formulation purposes. A palatable and economical energy source like corn or grain sorghum can be transformed into a nutritionally balanced ration if nutrient deficiencies are corrected by using additional ingredients.

Practical diet formulation must be sufficiently flexible to accommodate price and feedstuffs available while retaining the necessary nutritive balance and adequacy. When protein supplements are extremely expensive, it might be more economical to feed slightly less protein than recommended, even with a somewhat decreased rate of growth. Likewise, when protein supplements are inexpensive relative to grain, it is sometimes economical to supply a greater percentage of protein than is normally recommended, but the effects of nitrogen excretion must be considered.

Swine rations usually are formulated using cereal grains as base ingredients because they are low in fiber and high in energy. Corn is the most commonly fed grain; however, other grains such as sorghum grain, wheat, or barley may be used. All grains are deficient in protein quantity and quality, as well as minerals and vitamins. Corn is an excellent energy source, and soybean meal is an excellent amino acid source. Soybean meal can be fed as the only supplemental protein source for swine.

The nutrient content of grains is affected by factors such as type or cultivar, stage of maturity at harvest, soil and climatic conditions, location grown, and time in storage. Nutrient requirements of animals vary due to genetics, age, weight, sex, and function. Requirements may vary even in animals of the same weight. Therefore, diets usually are formulated taking into account variations in feedstuffs and requirements.

High energy, low-fiber diets are fed to swine, to meet the energy requirement for growing-finishing animals. Fat may be added to increase the energy density of the diet in growing-finishing pigs with low-feed intakes and in high-producing lactating sows. For gilt developer and gestation diets, lower energy and higher fiber levels can be used to control weight gains. Other specialty ingredients can be used in diet formulation, depending on the swine production phase (for example in nursery pig diets) or specific needs.

Logical Steps in Formulating a Diet

1. *Identify animals to be fed by age, weight, function, and specific conditions under which they are fed.* Penning and feeding in uniform lots allow a producer to more closely meet the requirement of the pig.
2. *Select a set of nutrient requirements or allowances most appropriate for the animals being fed.* An authoritative source of information is *Nutrient Requirements of Swine* authored by the National Research Council (NRC, 1998). Nutrient requirements depend on a variety of factors, such as stage of growth, lean growth potential, and environmental conditions. Tables 1, 2, and 3 show requirements for amino acids, minerals, and vitamins, respectively, which meet the requirements of swine raised under most production scenarios. Table 4 gives some conversion factors that are very useful in diet calculations.
3. *Select suitable ingredients to help ensure that the ration is nutritionally balanced, palatable, safe, and economical.* The inclusion of certain feed ingredients should be limited and some guidelines for using different feedstuffs are given in Table 5. Various feeding guides and example diets can be helpful in selecting feed ingredients. Average analyses of selected ingredients are presented in Table 6. However, for the most accurate feed formulation, feedstuffs to be used in the ration should be analyzed, and the values should be used in the formulation.

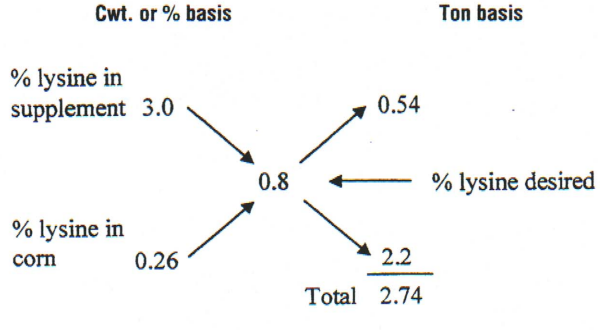
4. *Determine the necessary fixed amount of certain ingredients (minerals and vitamins) and then mix grain(s) relative to protein supplements to provide the desired level of amino acids.* Diets can be formulated using a computer ration formulation program or computed by hand. Formulation by computer allows the user to take multiple factors into account and is the superior and most used method of formulation. Calculations by hand can be useful if a diet formulation program is not available. In that case, the ration can be formulated on either a cwt (100 lbs) basis or on a ton basis, depending on personal preference. The advantage of cwt basis is that percentage figures for diet nutrients are the same as pound figures for diet nutrients. However, formulating diets on a ton basis can reduce calculation time required, particularly where cost per ton of diet ingredients is to be determined. The quantity of any particular ingredient may be determined by using feeding guides and personal experience. Precision in balancing a diet can be obtained with simultaneous equations or algebraic equations. However, the "Square Method" is most used in balancing diets because it is easy to use when blending two feeds or combinations of feed ingredients into a mixture containing a definite percentage of some nutritive factor.

Balancing Diets for Amino Acids

Diets should be balanced on an amino acid basis rather than on a crude protein basis. This provides a more precise indication of diet adequacy. For the purpose of this discussion, diets will be balanced on a total amino acid basis (i.e., the total content of certain amino acids of feed ingredients); although, formulation based on apparent or true ileal digestible amino acids may provide some additional precision (see PIH-5, "Protein and Amino Acids for Swine," Hays and Baker, 1998 for more details). Lysine is the amino acid recognized as most limiting in swine diets and is used to balance diets initially. Other essential amino acids will be present in sufficient quantities in corn-soybean meal based rations, but should be checked when using a variety of other ingredients or synthetic lysine.

The Square Method to Formulate Diets

Example 1: Combine a supplement containing 3% lysine and corn containing 0.26% lysine to make a 0.8% lysine ration.

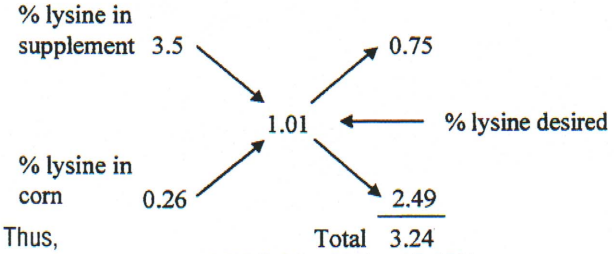


0.54/2.74 x 100 = 19.71% x 20 = 394 lbs. of supplement
2.2/2.74 x 100 = 80.29% x 20 = 1606 lbs. of corn
2000 lbs. total

Subtract on the diagonal the smaller number from the larger to obtain relative amounts of corn (3.0 – 0.8 = 2.2) and supplement (0.8 – 0.26 = 0.54). A 0.8% diet would be derived from 0.54 parts of the 3.0% supplement and 2.2 parts of the 0.26% corn. To put this on a percentage basis, divide 0.54 by 2.74 and multiply by 100 to get 19.71% supplement in the diet, and divide 2.2 by 2.74 and multiply by 100 to get 80.29% corn in the diet. Each of these percentage figures can be multiplied by 20 to put the inclusion rates on a ton basis. The lysine content of other grains, supplements, or mixtures can be substituted in the above formula to mix a diet of a desired lysine content.

Example 2: A 0.8% lysine diet is needed and it should contain 35% barley and an appropriate amount of corn and 3.5% lysine supplement. Barley contains 0.41% lysine and corn contains 0.26%. Because 35% of the diet is barley and contains 0.41% lysine, the remaining 65% of the diet must be considerably higher in lysine to give a 0.8% lysine diet.

35% x 0.41% lysine = 0.144% lysine from barley
0.8% lysine diet – 0.144% from barley = 0.656% lysine needed from corn and supplement
The corn and supplement portion is only 65%, so 0.656/65% = 1.01% lysine is needed in this 65% portion.



Thus,
% supplement = 0.75/3.24 x 65% = 15.05%
% corn = 2.49/3.24 x 65% = 49.95%

The above method may be used for any predetermined amount of any ingredient such as 5% fish meal, 10% alfalfa meal, 5% whey, 3% mineral and vitamin premix, etc.

Example 3: A 0.8% lysine ration is to contain equal parts of corn and barley balanced with soybean meal (without hulls; 48% CP). Assume further that 3% of the diet formula is needed for vitamins and minerals. Corn has 0.26% lysine and barley has 0.41%, which gives a 0.335% average for the two grains. Soybean meal contains 3.02% lysine. Because only 97% (3% is vitamins and minerals) of the diet contains lysine, that portion must contain 0.8/0.97 = 0.825% lysine.

Ingredient	% Inclusion	% Lysine	Total lysine
Barley	35.0	0.41	0.145
Corn	50.0	0.26	0.130
Supplement	15.0	3.5	0.525
Total	100.0		0.800

The diet should contain:
0.49/2.685 x 97% = 17.7% soybean meal
2.195/2.685 x 97% = 79.3% corn + barley (divided in equal parts)

Ingredient	% Inclusion	% Lysine	Total lysine
Barley	39.65	0.41	0.162
Corn	39.65	0.26	0.103
Soybean meal	17.70	3.02	0.535
Vitamin/Mineral	3.00	0	0
Total	100.00		0.800

Balancing Diets for Minerals

The following procedure is suggested for supplementing diets with minerals.

1. Use iodized salt and trace mineral mix or swine trace mineral containing salt in rations to meet sodium, chlorine, and trace mineral needs. A trace mineral mix may be available separate from a vitamin premix or as a combination vitamin-mineral premix. Check mineral levels to make sure they are provided in the correct amounts (Table 2).
2. Use calcium (Ca) and phosphorus (P) sources to meet requirements as shown in Table 2.

Example: Meet the requirements for a finishing pig (from 50 to 80 kg) of 0.50% Ca and 0.45% P in the diet from the previous example.

Step 1. Using ingredient composition from Table 6, calculate the Ca and P supplied from corn, barley, and soybean meal.

Step 2. Subtract the Ca and P supplied by corn, barley, and soybean meal from the requirement. Calcium is still short by 0.404%, and P is short by 0.078%.

Step 3. Meet the P requirement first because most P sources also contain some Ca (P sources are also more expensive than Ca sources). To determine the amount of P source to add, divide the amount required by the P content of the P source. Dicalcium phosphate contains 18.5% P and 22% Ca; therefore, 0.078/0.185 = 0.42% or 8.4 lbs. per ton (0.42 x 20 cwt. or .0042 x 2000 = 8.4 lbs./ton). Adding 0.42% dicalcium phosphate would meet the P requirement and provide 0.092% Ca (0.42% x 0.22% = 0.092%). This would leave a Ca shortage of 0.312% (0.404% – 0.092% = 0.312%).

Step 4. Provide enough ground limestone to meet the Ca shortage. Do not add excess limestone just because it is cheap. To determine the amount of ground limestone, divide the amount of Ca required by the Ca content of limestone. Limestone contains 38% Ca; therefore, 0.312/0.38 = 0.82% or 16.4 lbs. per ton (0.82 x 20 = 16.4 lbs./ton).

Ingredient	% Inclusion	% Ca	Total Ca	% P	Total P
Barley	39.65	0.06	0.024	0.35	0.139
Corn	39.65	0.03	0.012	0.28	0.111
Soybean meal	17.70	0.34	0.060	0.69	0.122
Vitamin/Mineral	3.00	0	0	0	0
Total	100.00		0.096		0.372
Requirement			0.50		0.45
Shortage			0.404		0.078

The complete formulation for the ration balanced for lysine, calcium, and phosphorus is:

Ingredient	% Inclusion	Lb./ton
Barley	39.65	793
Corn	39.65	793
Soybean meal	17.70	354
Dicalcium phosphate	0.42	8.4
Limestone	0.82	16.4
Vitamin/Mineral premix*	1.76	35.2
Total	100.00	2000.0

* Premix to contain salt, vitamins and trace minerals

This same system can be used with other feed ingredients. Calcium and phosphorus levels in each ingredient can be obtained from Table 6.

Balancing Diets for Vitamins

A premix is used to provide supplemental vitamins. Check Table 3 for recommended levels of added vitamins. To see if the recommended levels are met by a specific vitamin premix, multiply the units per pound of premix and the recommended pounds of premix per ton of diet to get the units per ton. Make sure the units are identical, or use the conversion factors in Table 4 to convert to the proper units.

Computer Feed Formulation

Computer formulation is the preferred method of diet or feed formulation and is available in most areas at a reasonable cost. This method provides additional alternatives of ingredient substitution and reduces time and chances of error in hand calculation. Many swine producers have access to computers to aid decision making. Computers can handle the calculations of diet formulation efficiently, allowing you to examine diets in more detail and evaluate alternatives. The computer can rapidly select combinations of feeds that will meet nutrient requirements; and, when cost data are provided, it will select those that meet the requirements at the lowest cost. Also, a computer can be used to analyze your current feeding program by checking diets against accepted nutrient requirements. However, the computer will not replace the nutritionist or farm manager. To properly use computers, several items are needed:

- Knowledge of diet specifications and requirements including minimum and maximum allowances on nutrients and ingredients
- Up-to-date ingredient information such as nutrient analysis and accurate on-farm prices

- Procedures for converting analysis, results, and feed tag information to a format that can be properly handled by the computer
- An organized system for updating information such as prices, results of analyses, and ingredient availability
- Access to a suitable program

Since feed cost represents a large portion of total swine production cost, a small savings can significantly reduce total cost. As swine producers become more knowledgeable and take advantage of the computer, consistency will improve swine-diet composition. The role of a computer is to calculate balanced diets at the least cost and to check them against requirements. Information on ingredient availability, nutrient content, and nutrient requirements is supplied by the user. Therefore, the accuracy of the results depends upon the detail and accuracy of the information supplied.

A simple computer spreadsheet can be accessed at http://mark.asci.ncsu.edu/nutrition/formulate.htm and can be used to analyze diets quickly. Nutrient composition of feedstuffs are already entered and the user can supply estimated inclusion rates for different ingredients. The calculated diet composition can then be compared with the nutrient requirement of different classes of swine.

Summary

Most diets are formulated in one of three ways:

1. Combining corn and/or other grains with a complete protein supplement, or
2. Combining corn and/or other grains with soybean meal and a complete vitamin-mineral premix (Table 7 shows examples using this method), or
3. Combining corn and/or other grains with soybean meal, a vitamin-premix, trace minerals, salt, calcium, and phosphorus (examples are shown in Table 8).

Further examples are given in PIH-23, "Swine Diets", Luce, Harper, Mahan, and Hollis, 1996).

Table 1. Total amino acid requirements of swine.

	Weight class/lbs.				Breeding herd	
Nutrient	**20-50**	**50-110**	**110-175**	**175-260**	**Gestation**	**Lactation**
Lysine	1.15	0.95	0.75	0.60	0.54	0.91
Methionine	0.30	0.25	0.20	0.16	0.14	0.23
Cystine	0.35	0.29	0.24	0.19	0.23	0.21
Threonine	0.74	0.61	0.51	0.41	0.45	0.58
Tryptophan	0.21	0.17	0.14	0.11	0.11	0.16

Source: NRC, 1998. Values were calculated for mixed gender (1:1 ratio of barrows and gilts) pigs with high-medium lean growth rate (325 g carcass fat-free lean per day).

Table 2. Mineral requirements of swine.

	Weight class/lbs.				Breeding herd	
Nutrient	**20-50**	**50-110**	**110-175**	**175-260**	**Gestation**	**Lactation**
Calcium, %	0.70	0.60	0.50	0.45	0.75	0.75
Phosphorus, %	0.60	0.50	0.45	0.40	0.60	0.60
Salt, %	0.35	0.35	0.35	0.35	0.50	0.50
Copper, ppm	10	10	10	10	10	10
Iron, ppm	100	100	100	100	100	100
Zinc, ppm	100	100	100	100	100	100
Manganese, ppm	20	20	20	20	20	20
Iodine, ppm	0.2	0.2	0.2	0.2	0.2	0.2
Selenium, ppm	0.25	0.15	0.15	0.15	0.15	0.15

Source: NRC, 1998 and PIH-52, "Minerals for Swine" (Cromwell, Mahan and Weldon, 1998).

Table 3. Suggested vitamin levels added per ton of swine feed.

Vitamin	Starter	Grower-finisher	Gestation-lactation[1]
Vitamin A, IU	4,500,000	2,700,000	4,500,000
Vitamin D, IU	500,000	300,000	500,000
Vitamin E, IU	25,000	15,000	25,000
Vitamin K, g	3.3	2	3.3
Riboflavin, g	6	3.6	6
Pantothenic acid, g	22.5	13.5	22.5
Niacin, g	35	21	35
Vitamin B_{12}, mg	25	15	25
Choline, g	—	—	100
Folic Acid, g	—	—	1.5
Biotin, mg	—	—	200

[1] Additional choline (550 g/ton) is recommended during gestation.

Source: PIH-2, "Vitamins for Swine" (Thaler and Wahlstrom, 1992).

Table 4. Conversion factors.

Equivalents	To convert	Conversion table			
		%	ppm	g/ton	mg/lb
1 pound (lb) = 454 grams (g)	mg/g to mg/lb - multiply by 454	0.0001 =	1.0 =	0.9 =	0.45
1 kilogram (kg) = 1,000 g = 2.2 lb	mcg/g to mg/g - divide by 1,000	0.00011=	1.1 =	1.0 =	0.50
1 g = 1,000 milligrams (mg)	mcg/lb to mg/lb - divide by 1,000	0.001 =	10.0 =	9.1 =	4.55
1 mg = 1,000 micrograms (mcg)	mg/lb to mcg/g - divide by 0.454	0.011 =	11.0 =	10 =	5.0
1 mg/kg = 1 part/million (ppm)	mg/lb to ppm - multiply by 2.2	0.01 =	100.0 =	90.8 =	45.4
1 mcg/lb = 2 mg/ton	g/lb to % - divide by 4.54	0.011 =	110.0 =	100.0 =	50.0
1 mg/lb = 2 g/ton	% to g/lb - multiply by 4.54	0.1 =	1000.0 =	908.0 =	454.0
1 mg/lb = 2.2 ppm		0.11 =	1100.0 =	1000.0 =	500.0
1 mcg/g = 1 ppm					

Table 5. Maximum recommended inclusion rates of feed ingredients for swine.

	Suggested maximum inclusion in complete diets, %			
Feedstuff	**Starter**	**Grow-finish**	**Gestation**	**Lactation**
Barley	25	85	80	80
Corn, grain	60	85	80	80
Sorghum, grain	60	85	80	80
Triticale, grain	20	85	80	80
Wheat, hard red winter	60	85	80	80
Wheat, soft red winter	60	85	80	80
Bakery product, dry	20	40	40	40
Brewers grains, dry	0	10	40	5
Beet pulp, dry	0	0	10	5
Corn distillers grain & solubles	5	10	40	10
Corn gluten feed	5	25	90	5
Corn grits byproduct (hominy)	0	60	60	60
Rice bran	0	20	40	5
Wheat bran	0	0	30	5
Wheat midds, < 9.5% CF	0	10	30	5
Blood meal, spray-dried	5	5	5	0
Canola meal	5	10	5	5
Corn gluten meal	0	5	5	5
Cottonseed meal	0	15*	5	5
Feather meal, hydrolyzed	0	3	3	3
Fishmeal, menhaden	5	5	5	5
Meat and bone meal	5	5	10	5
Peanut meal, mech. extr.	0	5	5	5
Poultry byproduct meal	0	5	10	5
Sunflower meal, dehulled	0	10	10	5

*For cottonseed meal with free gossypol levels of less than 1.05%, otherwise limit to 5%.

Source: Adapted from PIH-3, "Dietary Energy for Swine" (Holden, Shurson and Ewan, 2000) and PIH-112, "Relative Value of Feedstuffs for Swine" (Harper and Forsyth, 1998). Values are based on an air-dry basis.

Table 6. Nutrient composition of selected ingredients.

	Nutrient								
Ingredient	**ME/Lb**	**Ca, %**	**P, %**	**Lys, %**	**Met, %**	**Cys, %**	**Thr, %**	**Trp, %**	**CP, %**
Energy sources									
Barley, 2 row	1323	0.06	0.35	0.41	0.20	0.28	0.35	0.11	11.30
Corn gluten feed	1184	0.22	0.83	0.63	0.35	0.46	0.74	0.07	21.50
Corn, grain	1555	0.03	0.28	0.26	0.17	0.19	0.29	0.06	8.30
Sorghum, grain	1518	0.03	0.29	0.22	0.17	0.17	0.31	0.10	9.20
Triticale, grain	1445	0.05	0.33	0.39	0.20	0.26	0.36	0.14	12.50
Wheat, hard red winter	1459	0.06	0.37	0.34	0.20	0.29	0.37	0.15	13.50
Wheat, soft red winter	1502	0.04	0.39	0.38	0.22	0.27	0.39	0.26	11.50
Wheat midds, < 9.5% CF	1375	0.12	0.93	0.57	0.26	0.32	0.51	0.20	15.90
Choice white grease	3616	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poultry fat	3718	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Restaurant grease	3730	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Protein sources									
Soybean meal, sol. extr.	1445	0.32	0.65	2.83	0.61	0.70	1.73	0.61	43.80
Soybean ml, w/o hulls	1536	0.34	0.69	3.02	0.67	0.74	1.85	0.65	47.50
Corn gluten meal, 60% CP	1741	0.05	0.44	1.02	1.43	1.09	2.08	0.31	60.20
Meat meal, with bone	1011	9.99	4.98	2.51	0.68	0.50	1.59	0.28	51.50
Poultry byproduct meal	1300	4.46	2.41	3.32	1.11	0.65	2.18	0.48	64.10
L-Lysine-HCl	2032	0.00	0.00	78.80	0.00	0.00	0.00	0.00	94.40
DL-Methionine	2389	0.00	0.00	0.00	99.50	0.00	0.00	0.00	58.10
L-Threonine	1741	0.00	0.00	0.00	0.00	0.00	98.50	0.00	72.40
L-Tryptophan	2864	0.00	0.00	0.00	0.00	0.00	0.00	98.50	84.90
Mineral Sources									
Dicalcium Phosphate	0	22.00	18.50	0.00	0.00	0.00	0.00	0.00	0.00
Monocalcium Phosphate	0	17.00	21.10	0.00	0.00	0.00	0.00	0.00	0.00
Limestone	0	38.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: adapted from NRC, 1998.

Table 7. Example rations for different classes of swine using a vitamin-mineral premix[1].

	Weight class/lbs.				Breeding Herd	
Ingredient	**20-50**	**50-110**	**110-175**	**175-260**	**Gestation**	**Lactation**
Corn, grain	1273	1434	1585	1699	1715	1447
Soybean meal (High protein)	652	506	360	251	210	478
Vitamin-mineral Premix	75	60	55	50	75	75
Total	2000	2000	2000	2000	2000	2000
Lysine, %	1.15	0.95	0.75	0.60	0.54	0.91
Ca, %	0.70	0.60	0.50	0.45	0.75	0.75
P, %	0.60	0.50	0.45	0.40	0.60	0.60
ME, kcal/kg	3279	3307	3319	3329	3288	3282
Protein, %	20.8	18.0	15.1	13.0	12.1	17.4

[1] Check the vitamin-mineral premix to be used for the proper inclusion level. The premix in this example would contain vitamins, micro-minerals, salt, and a Ca and P source. Diets were formulated to contain the recommended nutrient levels from Tables 1, 2, and 3.

Table 8. Example diets for different classes of swine[1].

	Weight class/lb.				Breeding herd	
Ingredient	**20-50**	**50-110**	**110-175**	**175-260**	**Gestation**	**Lactation**
Corn, grain	1292	1445	1596	1708	1719	1457
Soybean meal (47.5% CP)	650	505	359	250	210	477
Dicalcium phosphate	21	13	11	8	31	25
Limestone	18	18	15	15	18	19
Salt	7	7	7	7	10	10
Micro-mineral premix	2	2	2	2	2	2
Vitamin premix	10	10	10	10	10	10
Total	2000	2000	2000	2000	2000	2000
Lysine, %	1.15	0.95	0.75	0.60	0.54	0.91
Ca, %	0.70	0.60	0.50	0.45	0.75	0.75
P, %	0.60	0.50	0.45	0.40	0.60	0.60
ME, kcal/kg	3308	3324	3335	3343	3294	3297
Protein, %	20.8	18.0	15.2	13.0	12.1	17.4

[1] Check PIH-23, "Swine Diets" (Luce, Harper, Mahan, and Hollis, 1996) for further examples. Diets were formulated to contain the recommended nutrient levels from Tables 1, 2, and 3.

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