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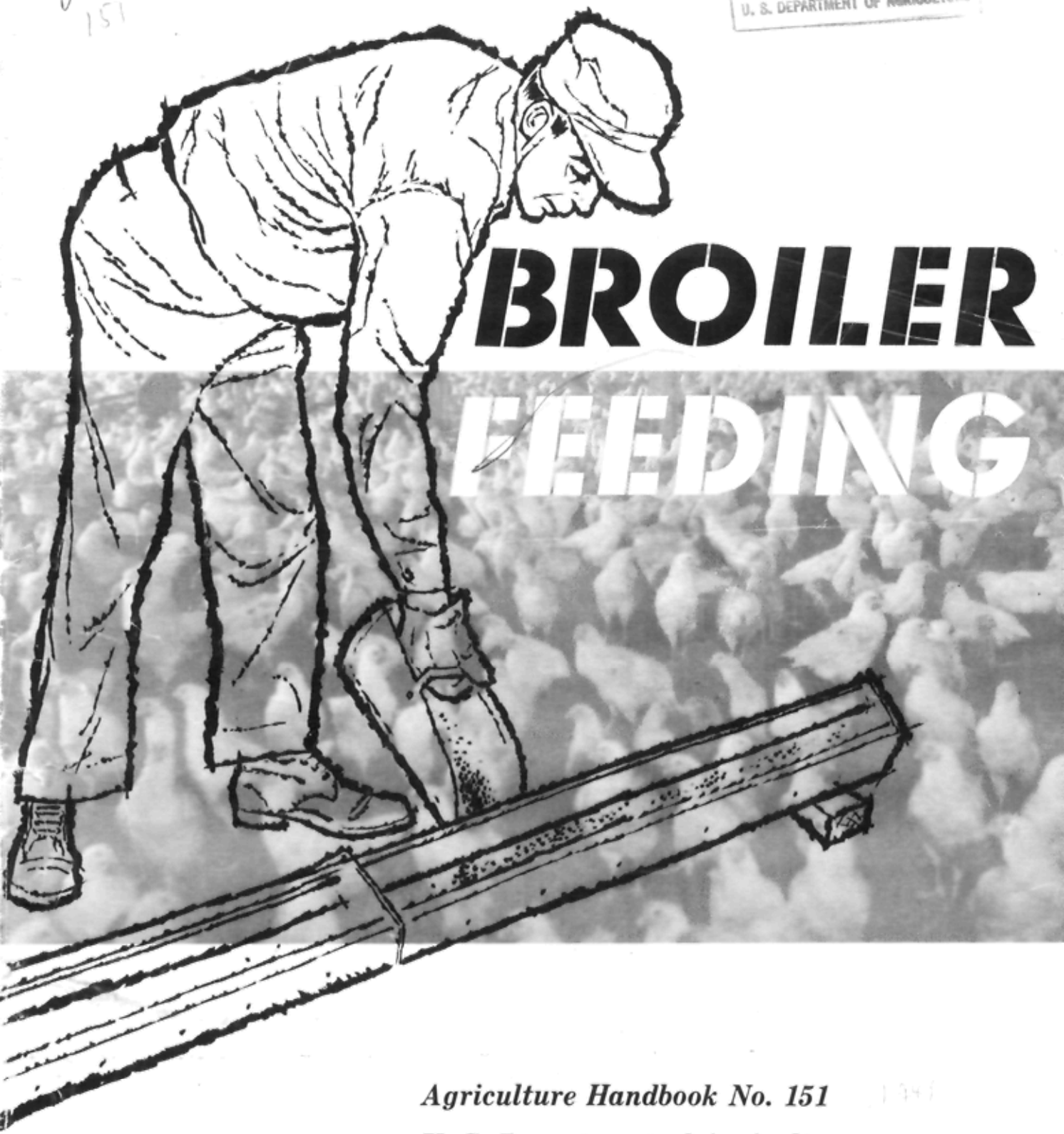

BROILER FEEDING

Agriculture Handbook No. 151

U. S. Department of Agriculture

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BROILER FEEDING

Broiler raising is one of agriculture's most efficient enterprises. Rations supplied broilers should produce a 3-pound bird with good feathering and pigmentation in 8 to 10 weeks at the least possible cost. An efficient conversion job can be done only if adequate amounts of the required materials are supplied in the proper balance.

NUTRIENT REQUIREMENTS

Broiler diets are made up of many nutrients. Research has determined the minimum amounts and, in some cases, maximum amounts necessary for good growth. It has been found that other dietary materials also are required if the bird is to reach a desired weight in the shortest length of time and at the lowest feed cost. Still other materials are included in the ration to improve market quality. Each of these nutrients and added materials is discussed in the following sections.

PROTEIN

Protein is the principal material used by the bird to build tissue. Starter diets that usually are fed the first 6 to 8 weeks should contain at least 22 to 24 percent of protein. The costs of protein ingredients may make it desirable to reduce this range to 17 to 19 percent for finishing off the broilers, because the bird's protein requirements gradually decline as it grows older. Reducing the protein level too soon or too much may be false economy. Too great a reduction in protein content reduces growth rate and feed efficiency to a point where the saving in feed cost is more than canceled out.

The total quantity of protein in the diet is important, but equally important is the quantity of each of certain amino acids found in protein. The amino acids are the parts that, fitted together, form the various kinds of plant and animal proteins. Eleven of these parts are considered essential—ten because they cannot be synthesized, or manufactured, by the bird, and an eleventh, glycine, because it cannot be synthesized by the bird in adequate amounts. Two additional amino acids, cystine and tyrosine, can be substituted in part for two that the chick cannot synthesize, methionine and phenylalanine. Requirements of the eleven essential amino acids are listed in table 1. Most efficient growth occurs when the essential ones are supplied in balanced amounts.

Animal protein sources, such as fishmeal, meat scrap, and dried milk, contain adequate quantities of the essential amino acids. The most commonly used vegetable proteins, soybean oil meal, and cottonseed meal, are relatively low in certain of the essential amino acids. When either of these two meals is used as the sole protein concentrate, the soybean oil meal diet may be deficient in methionine and the cottonseed meal diet is likely to be inadequate in lysine. Methionine is used as a dietary supplement. Lysine may be available commercially for this purpose. Cottonseed meal is used in broiler diets in combination with soybean oil meal, with animal proteins, or with both.

Processing conditions affect the amino acid availability and content of all protein materials. One of the most important of these conditions is heat exposure—both maximum temperatures and duration of heat exposure of the meal during processing. Meals that have not been heated excessively during processing usually are the most desirable protein concentrates.

CARBOHYDRATE AND FAT

Carbohydrate and fat serve primarily as fuel in the body although protein may also be used for this purpose. Excess amounts may be stored as body fat.

Carbohydrate is listed on feed analysis tags under two headings, nitrogen-free extract and crude fiber. Nitrogen-free extract is made up of starches and sugars that are readily utilized. Crude fiber is a woody material not readily

utilized by chickens and should not constitute more than 4 percent of a broiler diet. Principal sources of carbohydrate are the grains and their byproducts.

Fat is a concentrated source of energy that supplies approximately 2.25 times as much energy as the same weight of carbohydrate. A certain amount of fat is present in most feedstuffs used in poultry rations. Research has shown that adding fat as a separate ingredient improves feed efficiency and, in some cases, increases the rate of growth. In addition, it makes feeds less dusty and enhances their appearance, texture, and palatability. Equipment for mixing liquid fat with dry ingredients has been developed. Chemicals called antioxidants are added to the fat to reduce the likelihood of rancidity.

The amount of fat added to commercial broiler diets may range from 1 to 8 percent. In general, the proper amount to add is that which will result in the production of a pound of chicken for the least possible cost. This in turn will depend on improvement in growth and feed efficiency resulting from adding the fat, the price of fat, and the price of other dietary ingredients. Therefore, there is no specific recommended level that will be suitable for all conditions.

TABLE 1.—*Essential amino acid requirements for starting chicks* [1]

Amino acid	Requirement [2]
	Percent of ration
Arginine	1.20
Lysine	.90
Histidine	.15
Methionine [3]	.80
Tryptophan	.20
Glycine [4]	1.00
Phenylalanine [5]	1.60
Leucine	1.40
Isoleucine	.60
Threonine	.60
Valine	.80

[1] From *Nutrient Requirements for Poultry. A Report of the Committee on Animal Nutrition.* National Research Council Publication 301.

[2] Based on a diet containing 20 percent of protein.

[3] Cystine can be substituted for part of the methionine on the following basis: Cystine 0.35 percent and methionine 0.45 percent of the ration.

[4] The chick can synthesize glycine but the synthesis does not proceed at a rate sufficient for maximum growth.

[5] Tyrosine can be substituted for part of the phenylalanine on the following basis: Tyrosine 0.7 percent and phenylalanine 0.9 percent of the ration.

TABLE 2.—*Vitamin requirements for starting chicks*

Vitamin	Minimum requirement [1]	Recommended allowance [2]
	Per pound of feed	*Per pound of feed*
A [3]	1,200 USP [4]	4,400 USP.
D [5]	90 ICU [6]	400 ICU.
E [7]	7–11 IU [8]	
K [7]	0.180 mg	
B-complex:		
Thiamine	0.800 mg	0.9 mg.
Riboflavin	1.300 mg	2.3 mg.
Niacin	12.000 mg	24.0 mg.
Pantothenic acid	4.200 mg	6.4 mg.
Pyridoxine	1.300 mg	1.5 mg.
Biotin	0.040 mg	0.5 mg.
Choline [7]	600.000 mg	670.0 mg.
Folacin	0.250 mg	0.3 mg.
Vitamin B_{12} [7]	0.004 mg	

[1] From *Nutrient Requirements for Poultry. A Report of the Committee on Animal Nutrition.* National Research Council Publication 301. Amounts listed contain no margin of safety and refer to units of pure vitamin. Amount of vitamin supplements included in a ration will depend on the potency of the product used.

[2] It is felt that high-efficiency diets increase the requirement for several nutrients, particularly vitamins and protein.

[3] May be vitamin A or vitamin A precursor.

[4] USP (United States Pharmacopoeia) is the equivalent of 0.344 microgram of vitamin A acetate.

[5] May be vitamin D_3 from fish oil or irradiated animal sterol.

[6] ICU (International Chick Unit) is the equivalent of 0.025 microgram of pure vitamin D_3, a form of the vitamin used by poultry.

[7] Tentative—exact requirement not known.

[8] IU (International Unit) is the equivalent of 1 milligram of dl-alpha-tocopherol acetate.

The majority of broiler diets probably contain 2 to 4 percent of added fat, which brings their total fat content up to 6 to 8 percent. It is emphasized that, from a nutritional standpoint, fat is added only for the purpose of increasing the energy content of the diet. The amount of fat added is important only for its contribution to the total energy content of the diet, which is the sum of the energy derived from fat, carbohydrate, and protein.

The productive energy probably varies from 900 to 1,100 Calories [1] per pound in most broiler diets. For optimum feed efficiency the number of Calories in a diet should be related to the protein content. In research to discover the proper relationship between Calorie and protein content, no fixed ratio has been established. Good results have been ob-

[1] As used in this publication, "Calorie" equals 1 large calorie or 1,000 small calories.

tained with starting diets containing 42 to 45 Calories for each percent of protein and with finishing diets containing 50 Calories for each percent of protein.

VITAMINS

Vitamins are substances found in most natural feeds in extremely small amounts. Those considered necessary for growth and maintenance of health are: A, D, E, K, and the B complex, which includes thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, choline, folacin, and vitamin B_{12}. Requirements per pound of feed for these vitamins are listed in table 2. The requirements of E, K, and B_{12} are tentative, but research has shown that under most conditions these minimums are desirable. Recommended allowances are considerably above the minimum requirements listed; the purpose is to provide a safety margin to offset variation in vitamin content of feedstuffs and possible vitamin loss due to deterioration.

Vitamin A

Vitamin A is important for proper nerve function and helps to prevent infections of the eye and the respiratory tract. Deficiency retards growth and impairs the bird's health.

Dietary requirements may be met by adding fish oils, vitamin A concentrates, or plant materials that the animal can convert into vitamin A.

TABLE 3.—*Mineral requirements for starting chicks* [1]

Mineral	Minimum requirement	
	Percent of ration	*Milligrams per pound of feed*
Calcium	1.0	
Phosphorus [2]	.6	
Sodium	[3] .5	
Manganese		25.0
Iodine		.5
Iron [4]		9.0
Copper [4]		.9

[1] From *Nutrient Requirements for Poultry. A Report of the Committee on Animal Nutrition.* National Research Council Publication 301.

[2] At least 75 percent of the nutrition requirement for phosphorus should be of the inorganic type. All of the phosphorus of nonplant feed ingredients is considered to be inorganic and approximately 30 percent of the phosphorus of plant products may also be considered inorganic.

[3] This figure represents sodium chloride added as such or that in marine or fermentation products of high sodium chloride content.

[4] Tentative—exact requirement not known.

TABLE 4.—*Approximate composition of all-mash broiler rations by ingredient classes*

Class of ingredient	Percent of ration
Carbohydrate ingredients [1]	55–60
Vegetable-protein ingredients [2]	20–25
Animal-protein ingredients [3]	5–10
Vitamin-rich ingredients [4]	4–8
Stabilized fats [5]	0–8
Mineral carriers [6]	3–4
Miscellaneous ingredients [7]	

[1] Grains and grain byproducts: Corn, wheat, barley, oats, millet, shorts, middlings, red dog, hominy feed, etc.

[2] Soybean, cottonseed, and peanut meals.

[3] Fishmeal, fish solubles, meat scrap, liver meal, dried milk, feather meal, etc.

[4] Commercial vitamin supplements, alfalfa, dried whey, dried yeast, distillers' solubles, fermentation solubles, etc.

[5] Grease, tallow, etc.

[6] Limestone flour, oyster shell flour, dicalcium phosphate, steamed bonemeal, defluorinated superphosphate, defluorinated rock phosphate, iodized salt, manganese sulphate, etc.

[7] Trace amounts of these ingredients may be added. Many are present in commercial rations, but some may not be necessary under all conditions. The group includes antibiotics, coccidiostats, arsenicals, surfactants, hormones, antioxidants, and xanthophyll.

Alfalfa meal and yellow corn contain vitamin A precursors, or substances that form vitamin A. However, the amounts of the vitamin precursor in alfalfa meal and yellow corn usually are not considered in making up a formula. Sufficient amounts of vitamin A concentrates usually are added to meet the bird's full requirement.

Vitamin D

Vitamin D is essential for normal utilization of calcium and phosphorus in bone building. When it is not supplied in sufficient quantity, young chickens grow slowly and develop soft bones regardless of the amount of calcium and phosphorus in the diet.

The chicken synthesizes vitamin D when exposed to sunlight, but concentrates containing the vitamin (fish oils and irradiated animal sterols) are added to rations because broilers seldom are raised in sunlight. These concentrates should be premixed with ground corn, bran, middlings, alfalfa, or soybean meal, because intimate contact with minerals brings about rapid destruction of vitamin D activity.

Vitamin E

Adequate amounts of vitamin E prevent exudative diathesis and a condition known as "crazy

chick" disease, or encephalomalacia. Exudative diathesis is characterized by a swelling of fatty tissues just beneath the skin. Birds affected by crazy chick disease are unable to coordinate movements of their legs, wings, and neck.

Vitamin E is found in cereal grains, alfalfa meal, and liver meal. It usually is added to the diet in wheat germ oil or as alphatocopherol acetate. Like vitamin A, the destruction of vitamin E is accelerated by contact with rancid fat.

Vitamin K

Vitamin K is required to preserve the clotting power of the blood. A deficiency is marked by hemorrhages, which may occur in any part of the body. The vitamin can be obtained from meat scrap, fish products, or alfalfa meal.

Vitamin B Complex

RIBOFLAVIN.—Riboflavin is essential for normal growth and prevents curled-toe paralysis. It is widely distributed in feedstuffs and also available as a synthetic compound. Among the best natural sources are dried milk products and brewers' yeast. Riboflavin is reasonably stable under ordinary storage conditions.

CHOLINE.—Choline is one of the vitamins required for normal growth and is a factor in the prevention of perosis, or slipped tendon. The chick's requirement is met, in most diets, by the addition of choline supplement.

VITAMIN B_{12}.—Vitamin B_{12} is added to diets that contain no animal proteins, because vegetable proteins are deficient in this vitamin. Vitamin B_{12} is available as a commercial supplement.

OTHER REQUIRED VITAMINS.—Thiamine, niacin, pantothenic acid, pyridoxine, biotin, and folacin are present in adequate quantities in the feedstuffs normally included in diets. It is not considered necessary to add them separately, although extra quantities of niacin and pantothenic acid commonly are included in broiler diets

TABLE 5.—

Ingredient	Protein	Crude fat [7]	Fiber	Minerals		
				Calcium	Phosphorus	
					Inorganic [1]	Total
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Alfalfa meal, dehydrated	17.8	2.8	24.2	1.07	0.06	0.20
Barley, excluding Pacific Coast	12.7	1.9	5.4	.09	.12	.40
Barley, Pacific Coast	9.0	2.0	6.0	.60	----------	.30
Brewers' dried yeast	44.6	1.1	2.7	.13	.43	1.43
Buttermilk, dried	32.0	5.8	.4	1.34	.94	.94
Corn, yellow dent	8.9	3.9	2.0	.02	.09	.30
Corn gluten meal	42.9	2.3	4.0	.16	.12	.40
Cottonseed meal (expeller)	41.4	5.8	10.7	.18	.34	1.15
Cottonseed meal (solvent) [5]	41.6	1.6	11.0	.15	----------	1.10
Distillers' dried grains with solubles (corn)	27.2	9.3	9.0	.17	.20	.68
Distillers' dried solubles	26.9	9.1	3.8	.35	.40	1.37
Fat, stabilized	----------	100.0	----------	----------	----------	----------
Feathers, hydrolyzed poultry [3]	85.0	3.0	1.0	----------	----------	----------
Fishmeal, menhaden	61.0	7.7	.7	5.49	2.81	2.81
Fish solubles, condensed	31.4	6.5	.6	.61	.70	.70
Linseed oilmeal (solvent)	35.1	1.7	8.9	.40	.25	.83
Milo maize (sorghum)	11.3	2.9	2.2	.03	.09	.30
Meat and bone scraps	50.6	9.5	2.2	10.57	5.07	5.07
Meat scraps [5]	53.4	9.9	2.4	7.94	4.03	4.03
Oats, except Pacific Coast	12.0	4.6	11.0	.09	.12	.40
Oats, Pacific Coast	9.0	4.5	12.0	.10	----------	.35
Oats (feeding), rolled	15.0	6.3	2.0	.07	.12	.40
Peanut meal (solvent) [5]	47.4	1.2	13.1	.20	----------	.65
Poultry byproduct meal [3]	56.0	14.0	2.0	3.50	1.70	1.70
Skimmilk, dried	33.5	.9	.2	1.26	1.03	1.03
Soybean meal, solvent dehulled [5]	50.9	.8	2.8	.26	----------	.62
Soybean meal, solvent	45.8	.9	5.8	.32	.20	.67
Tankage, digester [5]	59.8	8.1	1.9	5.94	3.17	3.17
Wheat, hard	15.2	1.8	2.6	.05	.12	.40
Wheat bran	16.0	4.1	9.9	.14	.35	1.17
Wheat, standard middlings	17.2	4.6	7.6	.15	.27	.91
Wheat germ oil	----------	----------	----------	----------	----------	----------
Whey, dried	13.1	.5	.3	.90	.80	.80
Bonemeal, steamed	12.1	3.2	1.7	28.98	13.59	13.59
Calcium carbonate	0	0	0	36.59	0	0
Dicalcium phosphate	0	0	0	27.00	19.07	19.07
Defluorinated rock phosphate	0	0	0	34.00	14.50	14.50

[1] Poultry are better able to assimilate inorganic phosphorus than other types. At least 75 percent of the nutritive requirement for phosphorus should be of the inorganic type.

[3] Carotene values were obtained from NRC Publications 301 and 449 with the exception of alfalfa meal. The value for alfalfa meal was obtained from *1957 Feedstuffs Analysis* table.

because of the possibility that the addition is beneficial.

Minerals

Minerals have a number of functions in the bird's body. Some serve as structural materials for bones and tissue, while others are necessary for the production of enzymes and hormones. Calcium, phosphorus, sodium, manganese, iodine, magnesium, potassium, sulfur, and trace minerals such as iron, copper, molybdenum, selenium, and zinc all must be included in the bird's diet. Definite requirements of the first five minerals and tentative requirements of iron and copper have been established and are given in table 3. The others, with the possible exception of molybdenum, are believed to be furnished in sufficient amounts by the grains and feedstuffs used in broiler rations and do not have to be added as part of a mineral supplement.

CALCIUM AND PHOSPHORUS.—Calcium and phosphorus are bone-building materials that should be supplied in the required amounts and in the proper ratio. Both excesses and deficiencies should be avoided, because they interfere with growth and bone development.

The principal sources of calcium for broiler feeds are oyster-shell flour and high-calcium limestone. Available phosphorus is furnished in small quantities by vegetable-protein concentrates. Phosphoric acid is rich in phosphorus and seems to have commercial possibilities as a source of this mineral. Both calcium and phosphorus are supplied in liberal quantities by meat and fishmeals, bonemeal, and defluorinated calcium phosphates. Naturally occurring calcium-phosphate rock should not be fed, because usually it contains toxic amounts of fluorine.

SODIUM.—Sodium usually is added to broiler rations in the form of salt (sodium chloride).

Feedstuffs analysis

Vitamins						Amino acids							Productive energy	Metabolizable energy
Riboflavin	Niacin	Pantothenic acid	Choline	A	E	Methionine	Cystine	Methionine plus cystine	Arginine	Lysine	Tryptophan	Glycine		
Milligrams per pound	*Milligrams per pound*	*Milligrams per pound*	*Milligrams per pound*	*USP units per pound* [2]	*Milligrams per pound*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Calories per pound*	*Calories per pound* [4]
7.3	8.7	12.3	400	100,000	[3] 85.00	0.32	0.34	0.66	0.80	0.90	0.23	----------	[4] 217	348
.8	24.1	3.7	500	0	0	.12	.20	.32	.50	.30	.13	----------	[4] 813	1,255
.5	20.0	3.0	400	----------	----------	.19	.15	.34	.40	.22	.10	----------	800	----------
15.9	203.4	49.9	1,766	0	0	.70	.50	1.20	2.20	3.00	.50	[3] 1.7	572	----------
14.1	3.9	13.7	822	0	0	.70	.30	1.00	1.10	2.40	.50	.2	[4] 786	1,247
.5	9.8	2.6	200	2,215.8	[3] 1.70	.14	.15	.29	.40	.30	.08	.4	[4] 1,105	1,535
.7	22.7	4.7	150	12,328.4	0	1.00	.60	1.60	1.40	.80	.20	2.1	[4] 821	1,095
2.4	15.4	4.7	1,262	10	11.48	.50	1.00	1.50	3.30	1.60	.50	[3] 2.4	[4] 800	1,159
2.1	20.7	8.1	1,301	0	4.96	.60	[6] .86	1.46	[6] 3.50	1.60	.50	2.3	[3] 560	----------
3.9	30.4	5.0	1,123	2,832.2	0	.50	.30	.80	.90	.70	.10	[3] .5	891	----------
7.7	52.4	9.5	2,190	499.8	[3] 7.00	.60	.60	1.20	1.00	.90	.20	[3] 1.1	[4] 1,020	1,395
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	[4] 2,878	----------
.8	8.0	3.5	400	----------	----------	.52	2.30	2.82	5.60	1.50	.57	5.9	800	----------
2.2	25.4	4.1	1,663	0	[3] 9.50	1.80	1.00	2.80	4.00	5.30	.60	4.0	[4] 941	1,230
6.6	76.7	16.1	1,831	999.6	0	1.00	1.70	2.70	2.40	2.70	.80	2.3	[3] 440	----------
1.3	13.7	6.5	557	0	0	.50	.60	1.10	2.80	1.30	.50	1.8	[4] 507	692
.4	13.1	5.0	250	0	0	.16	.20	.36	.30	.30	.09	[3] .4	[4] 1,099	1,528
2.0	21.7	1.7	993	0	0	.70	.60	1.30	4.00	3.50	.20	2.0	[4] 874	1,152
2.4	25.8	2.2	887	0	0	.80	.60	1.40	3.70	3.80	.30	2.2	[4] 949	1,249
.4	8.2	6.8	450	0	0	.13	.22	.35	.60	.40	.14	----------	[4] 810	1,133
----------	----------	----------	----------	----------	----------	.19	.17	.36	.50	.30	.10	----------	800	----------
.6	4.5	6.6	505	0	0	.24	.27	.51	.96	.61	.21	----------	[4] 1,162	1,612
5.0	[3] 77.5	[3] 24.0	[3] 800	----------	----------	.40	----------	----------	5.90	2.30	.50	2.5	----------	----------
4.8	18.0	4.0	2,720	----------	----------	1.00	1.00	2.00	2.76	3.70	.41	2.9	880	----------
9.1	5.2	15.3	647	0	4.15	.80	.50	1.30	1.20	2.80	.40	.2	[4] 765	1,232
1.4	9.8	----------	1,255	0	0	[3] .87	[3] .68	[3] 1.55	[3] 3.10	[3] 3.00	[3] .58	2.7	[4] 790	1,142
1.5	12.2	6.6	1,247	0	0	.62	.66	1.28	3.20	2.90	.60	[3] 2.4	[4] 761	1,103
1.1	17.8	1.1	986	0	0	.80	----------	----------	3.60	4.00	.70	----------	[4] 814	1,198
.5	24.1	6.3	450	0	0	.21	.24	.45	.50	.40	.16	----------	[4] 897	1,381
1.4	95.1	13.2	491	0	4.49	.10	.30	.40	1.00	.60	.30	[3] .9	[4] 494	759
.9	44.8	9.0	488	0	9.50	.20	.20	.40	.90	.70	.20	[3] .4	[4] 694	1,043
----------	----------	----------	----------	----------	60.30	----------	----------	----------	----------	----------	----------	----------	----------	----------
8.1	5.1	22.4	914	0	0	.15	.31	.46	.20	.80	.10	[3] .7	[4] 786	1,242
.4	1.1	1.9	0	0	0	0	0	0	0	0	0	0	300	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[3] From *1957 Feedstuffs Analysis* table.
[4] From *Energy Values of Feedstuffs for Poultry*. Titus (1955).
[5] From NRC Publication 449, June 1956.
[6] From NRC Publication 301, January 1954.
[7] Also called ether extract and includes all ether-soluble materials.

MANGANESE.—Manganese is present in nearly all ingredients of poultry feeds but not in sufficient quantity to insure an adequate supply. Dietary requirements may be met by adding manganese sulfate tetrahydrate. Lack of this mineral is a cause of perosis, or slipped tendon, in chicks.

IODINE.—The iodine content of feedstuffs is variable. Dietary requirements may be met by adding commercial iodized salt to poultry rations. An iodine deficiency leads to goiter formation, an enlargement of the thyroid gland of the neck.

IRON AND COPPER.—A deficiency of iron or copper results in nutritional anemia, but rarely occurs in practical diets. The grains and vegetable proteins used in broiler rations contain adequate amounts of these minerals and adding them separately is not considered necessary.

Miscellaneous Materials

UNIDENTIFIED GROWTH FACTORS.—Certain unidentified factors are known to be important in animal nutrition. Three of these are well recognized and are called the "whey," "fish," and "alfalfa" factors.

The whey factor is thought to be present in distillers' solubles, distillers' molasses solubles, brewers' yeast, butyl fermentation solubles, and dried whey.

The fish factor is thought to be present in fishmeal, fish solubles, crab meal, meat byproducts, liver preparations, and certain fermentation products.

The alfalfa factor is thought to be present in dehydrated alfalfa leaf meal, grass juice concentrate, and dried brewers' yeast.

ANTIBIOTICS AND COCCIDIOSTATS.—Antibiotics are added to rations either to stimulate growth or in connection with disease in the flock. The most commonly used ones are penicillin, chlortetracycline, oxytetracycline, and bacitracin. The addition of 4 to 5 grams of penicillin or 8 to 10 grams of the other antibiotics to a ton of feed usually results in lower flock mortality, more rapid growth, and greater feed efficiency. Addition of certain antibiotics at 100 to 250 grams per ton appears to be of value in reducing mortality and restoring birds to a healthy condition during outbreaks of some diseases. Most commercial broiler rations contain antibiotics at the lower level.

Coccidiostats are drugs added to rations to prevent or control the intestinal disease coccidiosis. Low levels of these drugs, included in a ration, enable birds to build up natural immunity. Higher levels help to control acute attacks of coccidiosis, but control generally is achieved more quickly by the addition of water-soluble coccidiostats to the drinking water.

A number of coccidiostats are in use, including sulfaquinoxaline, sulfamethazine, nitrophenide, and nitrofurazone. They should be used only at dosages recommended by the drug manufacturer since higher concentrations may be toxic.

ARSENICALS.—Another group of compounds that are used as growth stimulants is the arsenicals. Although toxic at higher levels, small amounts have effects similar to the antibiotics. There is experimental evidence that an arsenical, plus an antibiotic in some cases, provides a growth response greater than either alone. There also is some evidence that arsenicals may improve pigmentation. Because of these two possibilities, most commercial broiler diets contain an arsenical.

The two commonly accepted arsenicals are arsonic acid (3-nitro, 4 hydroxyphenylarsonic acid), and arsanilic acid (para-amino-hydroxyphenylarsonic acid). Arsonic acid usually is used at 45 grams per ton and arsanilic acid at 90 grams per ton.

SURFACTANTS.—Surfactants, also known as detergents, may stimulate growth. Few commercial broiler feeds contain surfactants, because there is little evidence that they provide growth stimulation beyond that provided by antibiotics.

HORMONES.—Hormones are gland secretions that regulate body functions. Estrogen, the female sex hormone, causes increased fat deposition under the skin of the bird and results in higher carcass quality. Synthetic chemical compounds have been discovered that have the same effect as this natural hormone. The best known of these compounds is diethylstilbestrol, which came into use as a pellet and a paste for implantation in the neck of the bird. Another compound, dienestrol diacetate, has been mixed with feed for the same purpose. Broiler rations that contain this compound are available. Feed manufacturers are required to comply with regulations of the United States Food and Drug Administration and of State feed control officials before marketing broiler rations that contain dienestrol diacetate.

ANTIOXIDANTS.—Antioxidants are chemical preservatives included in feeds to lessen the loss of

TABLE 6.—*All-mash broiler diets*

Ingredient	Diet number							
	Starting diets						Finishing diets	
	1	2	3	4	5	6	7	8
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Ground yellow corn [1]	59.40	53.94	59.34	55.49	59.54	57.94	64.62	66.61
Ground wheat [2]				5.00	5.00			
Animal fat [3]		4.00		4.00		4.00	1.00	
Fishmeal (60 percent)	6.00	5.00	5.00	5.00	5.00		5.00	5.00
Meat scraps				1.00	1.00			
Poultry byproduct meal	5.00		2.50			7.50	2.50	2.50
Feathers, hydrolyzed poultry						6.00		
Corn gluten meal	4.00	2.50	2.50	3.00	3.00	1.25		
Soybean meal, solvent [4]	18.00	25.50	22.00	10.00	10.00		18.00	16.50
Soybean meal, solvent dehulled						16.00		
Cottonseed meal, solvent				8.00	8.00			
Dried whey		2.00	1.50	2.00	2.00		2.00	1.50
Alfalfa meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Dried distillers' solubles	2.50	1.50	1.00			1.50	1.00	2.00
Calcium carbonate	1.25	.75	1.35	1.50	1.50	1.00	1.00	1.00
Defluorinated rock phosphate				1.50	1.50			
Dicalcium phosphate	.60					1.50		
Bonemeal, steamed		1.50	1.50				1.50	1.50
Salt, iodized	.30	.30	.30	.40	.40	.30	.30	.30
Manganese sulfate (65 percent grade) [5]	.05	.05	.05	.05	.05	.05	.05	.05
Vitamin A supplement (4,000 USP units per gram) [5]	.05	.05	.05	.05	.05	.05	.05	.05
Vitamin D_3 supplement (1,500 ICU per gram) [5]	.06	.06	.06	.06	.06	.06	.06	.06
Vitamin B_{12} supplement (12 milligrams per pound) [5]	.05	.05	.05	.05	.05	.05	.05	.05
Riboflavin supplement (227 milligrams per pound) [5]	.50	.50	.50	.50	.50	.50	.50	.50
Choline supplement (25 percent grade) [5 6]	.10	.10	.10	.15	.10	.10	.10	.10
DL-methionine (feed grade) [5]	.04	.10	.10	.15	.15	.10	.17	.18
Antibiotic supplement (10 grams per pound) [5]	.05	.05	.05	.05	.05	.05	.05	.05
Arsonic acid (10 percent) [5 7]	.05	.05	.05	.05	.05	.05	.05	.05
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Grams per ton	*Grams per ton*	*Grams per ton*	*Grams per ton*	*Grams per ton*	*Grams per ton*	*Grams per ton*	*Grams per ton*
Coccidiostat [8]	+	+	+	+	+	+	+	+
Niacin	25	25	25	25	25	25	25	25
Calcium pantothenate	5	5	5	5	5	5	5	5
Vitamin E [5]	5	5	5	5	5	5	5	5
Vitamin K	1	1	1	1	1	1	1	1
	Calculated analysis							
Crude protein, percent	22.7	23.9	21.7	21.5	21.8	23.9	19.3	19.0
Productive energy, calories per pound	956	1,008	939	892	925	1,026	980	968
Calorie-protein ratio [9]	42.0	42.1	43.3	41.4	42.4	42.9	50.0	50.9
Crude fat, percent	4.0	6.9	3.5	7.10	3.26	7.9	4.6	3.7
Crude fiber, percent	3.1	3.3	3.2	3.4	3.5	2.4	2.9	2.9
Calcium, percent	1.24	1.14	1.43	1.53	1.53	1.13	1.29	1.29
Phosphorus, total, percent	.72	.73	.75	.77	.79	.72	.74	.75
Phosphorus, inorganic, percent	.47	.47	.51	.58	.59	.51	.50	.50
Vitamin A, USP units per pound	4,717	4,410	4,530	4,506	4,596	4,345	4,339	4,383
Vitamin D_3, ICU per pound	409	409	409	409	409	409	409	409
Riboflavin, milligrams per pound	2.44	2.29	2.36	2.22	2.24	2.33	2.3	2.3
Niacin, milligrams per pound	25.3	23.8	24.1	24.5	24.9	22.8	23.5	24.0
Pantothenic acid, milligrams per pound	6.3	6.7	6.6	6.6	6.7	5.0	6.4	6.4
Choline, milligrams per pound	760	685	705	655	607	700	667	666
Methionine, percent	.45	.47	.47	.49	.49	.45	.50	.51
Cystine, percent	.36	.34	.34	.32	.32	.43	.31	.29
Methionine+cystine, percent	.81	.81	.81	.81	.81	.88	.81	.80
Arginine, percent	1.29	1.31	1.28	1.15	1.16	1.32	1.13	1.10
Lysine, percent	1.28	1.24	1.23	.97	.98	1.06	1.12	1.09
Tryptophan, percent	.23	.24	.23	.20	.20	.22	.21	.20
Glycine, percent	1.17	1.11	1.11	.95	.96	1.28	.99	.97

[1] Milo maize may be substituted for corn if the fat and vitamin A deficiencies of maize are compensated for. Barley may be substituted for corn if the productive energy and vitamin A deficiencies of barley are compensated for. Xanthophyll should be added for pigmentation.
[2] Oats or barley may be substituted for ground wheat if the formula is adjusted for the differences in productive energy and vitamin content.
[3] Should be stabilized with an antioxidant.
[4] Degossypolized cottonseed meal (meal containing 0.04 percent or less of free gossypol) may replace up to 50 percent of soybean meal in broiler diets.
[5] May be supplied in the form of a supplement or as a pure product providing the amounts used are adjusted to meet the bird's requirement for the pure product.
[6] Contains 25 percent choline chloride.
[7] Contains 10 percent 3-nitro, 4 hydroxyphenylarsonic acid.
[8] Feed at level recommended by manufacturer.
[9] Figures represent the number of Calories per pound of feed for each 1 percent of protein.

fat-soluble vitamins (A, D, E, and K) and to retard the rancidity of added fats. The two most commonly used antioxidants for poultry feeds are BHA (butylated hydroxyanisole) and BHT (butylated hydroxytoluene). Either or both may be added to poultry rations in line with limitations set by the United States Food and Drug Administration and State feed control officials.

XANTHOPHYLL.—Xanthophyll is the pigment that imparts yellow color to the skin and shanks of broilers. Yellow corn, corn gluten meal, and alfalfa meal are good sources of the pigment. If

TABLE 7.—*Sample worksheet showing*

Ingredient	Proportion of total diet		Productive energy, Calories per pound [2]	Protein [2]	Crude fat [2]	Fiber [2]	Vitamins				
							A	D	E	K	Riboflavin
	Percent	*Pounds per ton*	*Calories*	*Pounds per ton*	*Pounds per ton*	*Pounds per ton*	*USP [4] per ton*	*ICU [5] per ton*	*Grams per ton*	*Grams per ton*	*Milligrams per ton*
Yellow corn	59.40	1,188	1,312,740	105.73	46.33	23.76	2,632,370				594
Fishmeal (60 percent)	6.00	120	112,920	73.20	9.24	.84					264
Poultry byproducts meal	5.00	100	88,000	56.00	14.00	2.00					480
Corn gluten meal	4.00	80	65,680	34.32	1.84	3.20	986,272				56
Soybean meal, solvent	18.00	360	273,600	168.88	3.24	20.88					540
Alfalfa meal	2.00	40	8,680	7.12	1.12	9.68	4,000,000				292
Dried distillers' solubles	2.50	50	51,000	13.45	4.55	1.90					385
Calcium carbonate	1.25	25									
Dicalcium phosphate	.60	12									
Salt, iodized	.30	6									
Manganese sulfate (65 percent)	.05	1									
Vitamin A supplement (4,000 USP units per gram).	.05	1					1,816,000				
Vitamin D_3 supplement (1,500 ICU per gram).	.06	1.2						817,200			
Vitamin B_{12} supplement (12 milligrams per pound).	.05	1									
Riboflavin supplement (227 milligrams per pound).	.50	10									2,270
Choline CL (25 percent)	.10	2									
DL-methionine	.04	.8									
Antibiotic supplement (10 grams per pound).	.05	1									
Arsenic acid (10 percent)	.05	1									
Niacin											
Pantothenic acid											
Vitamin E									5		
Vitamin K										1	
Total per ton	100.00	2,000.0	1,912,620	454.90	80.32	62.26	9,434,642	817,200	5	1	4,881
Total per 100 pounds [6]			95,631	22.75	4.02	3.11	471,732	40,875	.25		244
Total per pound [7]			956				4,717	409	[8] .0025		2.44
Recommended allowance				22.24			4,400	400			2.30

[1] Diet analyzed is all-mash starting diet No. 1, table 6.

[2] Nutrient and energy content of each ingredient is calculated by multiplying the pounds used by the average composition figures given in table 5. That is, 1,188 pounds of corn (column 3) 8.9 percent protein (table 5) = 105.73 pounds of protein (column 5).

[3] Poultry are better able to assimilate inorganic phosphorus than other types. At least 75 percent of the nutritive requirement for phosphorus should be of the inorganic type.

[4] USP (United States Pharmacopoeia) is the equivalent of 0.344 microgram of vitamin A acetate.

the feedstuffs do not give the skin and shank a sufficiently deep color, additional xanthophyll can be added to the feed separately. Healthy birds generally show better pigmentation on any diet. For this reason, many ingredients may appear to have an effect on pigmentation (see Arsenicals, p. 8).

FORMULATION AND PREPARATION

Diet formulation refers to the selection of a particular ingredient combination that meets specific requirements. Preparation refers to the actual mixing of the ingredients chosen and the processing of the mixture to obtain a desired texture or form.

FORMULATION

In the formulation of a broiler ration, there are two steps: (1) Specific ingredients are chosen, and (2) amounts of each ingredient are calculated.

One of the principal considerations in choosing ingredients is their nutrient content. Most feed ingredients provide more than one of the required nutrients, but certain ones are rich in a particular nutrient. On this basis they can be divided into seven broad classes: Carbohydrates, vegetable proteins, animal proteins, vitamin-rich ingredients, stabilized fats, mineral carriers, and a miscellaneous group that includes ingredients added in trace amounts. These seven classes are listed in table 4, with a percentage range to show the approximate composition of all-mash rations.

Choice of ingredients within a class depends largely on availability and price. In various parts of the country and in different seasons of the year, certain ingredients are available in quantity. Because plentiful ingredients usually are lower in price than scarce ones, the feed mixer should choose the ingredients that can be combined to provide the maximum nutritive value at the lowest possible cost. The resulting ration may not be the lowest priced mixture, but should be one that meets nutritive requirements, makes possible rapid growth, low mortality, a quality carcass, and, at the same time, produces broiler

calculation of nutrient content of a proposed diet [1]

Vitamins—Continued			Minerals				Miscellaneous materials		Amino acids					
Niacin	Pantothenic acid	Choline	Calcium [2]	Phosphorus [2] Inorganic [3]	Phosphorus [2] Total	Manganese	Antibiotic	Arsenical	Methionine [2]	Cystine [2]	Arginine [2]	Lysine [2]	Tryptophan [2]	Glycine [2]
Milligrams per ton	*Milligrams per ton*	*Milligrams per ton*	*Pounds per ton*	*Pounds per ton*	*Pounds per ton*	*Grams per ton*	*Grams per ton*	*Grams per ton*	*Percent of diet*	*Percent of diet*	*Percent of diet*	*Percent of diet*	*Percent of diet*	*Percent of diet*
11,642	3,088	237,600	0.238	1.069	3.564				0.083	0.89	0.238	0.178	0.048	0.238
3,048	492	199,560	6.588	3.370	3.370				.108	.060	.240	.318	.036	.240
1,800	400	272,000	3.500	1.700	1.700				.050	.050	.138	.185	.021	.145
1,816	376	12,000	.128	.096	.320				.040	.024	.056	.032	.008	.084
4,392	2,376	448,920	1.152	.720	2.412				.112	.119	.576	.522	.108	.432
348	492	16,000	.680	.024	.080				.006	.007	.016	.018	.005	
2,620	475	109,500	.175	.200	.685				.015	.015	.025	.023	.005	.028
			9.147											
			3.240	2.280	2.280									
						72.6								
		227,000												
									.04					
							10							
								45						
25,000														
	5,000													
50,666	12,699	1,522,580	24.848	9.459	14.411	72.6	10	45	.454	.364	1.289	1.276	.231	1.167
2,533	635	76,129	1.242	.472	.73	3.63			.454	.364	1.289	1.276	.231	1.167
25.33	6.35	761.3				[9] .0363			.454	.364	1.289	1.276	.231	1.167
24.00	6.40	670.0	1.000	.45	.60	25.00			.450	.350	1.200	.900	.20	1.000

[5] ICU (International Chick Units) are the equivalent of 0.025 microgram of pure vitamin D_3, a form of the vitamin used by poultry.

[6] Dividing total per ton by 20 (20 hundredweight=1 ton) gives the energy and nutrient content per hundredweight. When this figure is in pounds, it is the same as the percentage of the mixture. Figures on this line may be checked against the nutritive requirements in the text and in tables 1 and 3.

[7] Dividing totals per ton by 2,000 gives energy and nutrient content per pound. Figures on this line may be checked against nutritive requirements in the text and in tables 1, 2, and 3.

[8] 0.025 grams=10,000 I U.

[9] 0.0363 grams=36.3 milligrams.

meat at the lowest possible cost per pound. To produce such a ration, consideration also should be given to palatability and quality of the ingredients. Palatability is important since broilers must consume large amounts of feed to make rapid gains, and ingredient quality is important to meeting nutritional requirements.

The amount of each ingredient that goes into the formula depends on its nutritive content. The average composition of the most commonly used broiler-feed ingredients is given in table 5; samples of an ingredient may contain more or less of a specific substance than is listed.

The information in table 5 enables the feed mixer to choose ingredients and ingredient amounts for formulating various broiler diets. There is no "best" diet. A number of combinations can be devised that will provide an efficient, economical ration.

SPECIMEN DIETS

Eight specimen all-mash diets are given in table 6. Six of these are rations that may be fed from starting time to market. Two are finishing diets that may be fed to the birds after the seventh week. Ingredient contents of the diets differ somewhat; one may be more desirable than the others in a particular part of the country, because of ingredient availability. All of the diets meet the nutritive requirements of broilers and will give a good rate of growth and feed efficiency under proper conditions, assuming average quality of all ingredients.

Broiler finishing diets are lower in protein and vitamin content, because the requirements for these nutrients decline as the birds grow older. Many broiler growers prefer to feed the starting ration the entire period, but finishing rations normally are lower in price than starting rations.

A method of checking a feed formula to be sure that it meets nutritive requirements is illustrated in table 7. This table may be used to calculate the nutritive content of any feed formula. The ingredients to be included are listed in column 1, and the percentage of each ingredient is listed

in column 2. Column 3 can then be filled in by calculating the pounds of each ingredient that would be included in a ton mixture.

The nutrient content of each ingredient then is calculated by multiplying the pounds used by the average composition figures given in table 5, and filling in the results under the proper headings in table 7.

NOTE.—In the diet analyzed in table 7, corn represents 59.4 percent of the diet, and 59.4 percent of 2,000 is 1,188, the number of pounds of corn used in this diet to mix a 2,000-pound batch. In this diet 1,188 pounds of corn (column 3) × 8.9 percent of protein (table 5) = 105.73 pounds of protein, which is entered in column 5.

When the table is filled in with the figures for a particular feed formula, the columns are totaled; this gives the nutritive content of a ton of feed. These totals then can be divided by 20 to obtain the nutrient content per hundredweight. When this figure is in pounds, it is the same as the percentage of the mixture. Figures on this line then may be checked against nutritive requirements in the text and in tables 1 and 3.

Dividing the total by 2,000 gives the nutritive content per pound of feed, and these figures can be used to check the requirements of those nutrients and materials required in very small amounts (tables 1, 2, and 3).

MIXING

Mixing is an important step in the preparation of an efficient economical ration. A baby chick eats about a thimbleful of feed a day. That thimbleful must meet all of the bird's nutritional requirements. Because only trace amounts of some ingredients are included in a ton of feed, a thorough mixing job is necessary if each thimbleful is to contain the nutrients in the proper proportions.

PROCESSING

After the feed is mixed, it may be processed further to obtain a desired form or texture.

Pellets probably are the most common form of processed feed. They usually are fed on top of the mash in hope of increasing feed intake and rate of growth. Pellets sometimes are fed as the entire ration, but the practice frequently results in cannibalism, particularly when the birds are confined.

Granules are another form of processed feed that is offered broiler raisers. They commonly are manufactured by breaking up pelleted feed into small particles, but a similar coarse-textured feed can be produced by using coarsely ground ingredients in the mixture. Birds seem to prefer a coarse feed to a fine, powdery mash. They tend to consume more and grow faster.

The extra processing necessary to produce pellets or granules makes them higher in price than coarsely ground mash.

FEED EVALUATION

Complete evaluation of feed formulas cannot be done on paper. Worksheets may show that a particular mixture meets nutritional requirements and is the lowest priced of those compared. But no method of calculating the amount of a particular feed that will be required to produce a pound of meat has been devised.

The most desirable feed or feed formula can be chosen by comparing the results of properly run feeding tests. Feeds being tested should be fed simultaneously to separate flocks of the same breeding and sex. All flocks should be sold at the same time, and careful records should be maintained throughout the feeding period.

Records should include figures for total feed consumed, total feed cost, total pounds of meat sold, and total dollars received for each flock. With these figures, the broiler raiser can compare the feeds tested, in three ways:

1. *Pounds of feed required to produce a pound of meat* can be determined by dividing the pounds of meat sold into pounds of feed fed, for each flock.

2. *Feed cost of a pound of meat* can be determined by dividing pounds of meat sold into total feed cost, for each flock.

3. *Income over feed cost* can be determined by subtracting feed cost from dollars received, for each flock.

The results of these calculations will enable the feeder to make a comparison of different feeds and assist him in deciding which feed or feed formula is best suited to his purpose.

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