FEEDS AND FEED ADDITIVES, NONRUMINANT FEEDS

1. Introduction

Meat and eggs produced by nonruminants, ie, swine and poultry, in the United States contribute significantly toward meeting the nutritional requirements of the human population. In 2001, the average per capita food consumption (retail cut equivalent) in the United States included 23.6 kg of pork, 8.2 kg of turkey, 31.8 kg of broilers, and 259 eggs. This was supplied by 98 million hogs, 270 million turkeys, 5.3 billion broilers, and 327 million laying hens (1). The feed required to produce such a quantity of meat and eggs is considerable.

Most poultry production, and a growing percentage of swine production, takes place in intensive, confinement operations. Much of the poultry production is carried out under a system of vertical integration in which a producer hatches the chicks; grows them in the producer's facilities; or in contract facilities, provides the feed, processes the animals, and markets the product. This system of vertically integrated production is not as common in the swine industry.

2. Feed Ingredients

Both swine and poultry diets are comprised primarily of grains such as corn and grain sorghum, with occasional use of wheat, barley, and other small grains (see WHEAT AND OTHER CEREAL GRAINS). Soybean meal is the primary source of protein in these diets, but animal by-products such as meat and bone meal, poultry by-product meal, feather meal, and fish meal contribute significant amounts of protein and provide some of the minerals required for growth, maintenance, reproduction, and lactation (see SOYBEANS AND OTHER OILSEEDS). Many human and industrial by-products are also used in swine and poultry feeds, eg, dried bakery products, produced from leftover bread and other bakery waste; inedible fats from the processing of vegetable oils for human consumption; large amounts of fats and oils from the restaurant and fast food trade that are produced as by-products of cooking food; and numerous other products that would otherwise go unused. An excellent review of the characteristics of many common feed ingredients is available (2), as are nutrient composition tables for ingredients most commonly used in animal feeds (3). An estimation of the principal feedstuffs used in animal feeds is given in Table 1.

Table 1. **Feed Ingredient Usage by the Livestock and Poultry Industry,[a] 2000[b,c] 10^3 tons**

Ingredient	Amount
Grains	
corn	139,000
sorghum	6,700
oats	2,800
barley	3,100
wheat and rye	6,920
Oilseed meals	
soybean	27,816
cottonseed	2,299
linseed	158
peanut	97
sunflower	576
canola	1,462
Animal protein	
tankage and meat meal	2,378
fish meal and solubles	276
milk products	356
Other	
gluten feed and meal	3,365
wheat millfeed	6,409
rice millfeed	534
alfalfa meal	204
fats and oils	1,458
miscellaneous	1,461

[a] Includes ruminants and nonruminants.
[b] Values given are estimates.
[c] Ref. 4.

Because of the simplicity of swine and poultry feeds, most feed manufacturers add vitamins (qv) and trace minerals to ensure an adequate supply of essential nutrients. Amino acids (qv) such as methionine [7005-18-7], lysine [56-87-1], threonine [36676-50-3], and tryptophan [6912-86-3], produced by chemical synthesis or by fermentation (qv), are used to fortify swine and poultry diets. The use of these supplements to provide the essential amino acids permits diets with lower total crude protein content.

Virtually all broiler and turkey diets, and much of the swine feeds, are pelleted prior to feeding. Pelleted feeds are consumed in greater quantity than are feeds in a mash or meal form, and generally result in more rapid weight gain and better feed conversion. Proper pelleting of feed also aids in reducing the potential of salmonellas or other bacterial contamination of feeds. Pelleting is accomplished by forcing the feed through a die having many small holes. Pelleting is improved by steaming the feed to gelatinize the starch provided by the grains, by adding low (<2%) levels of fat to the feed, or by addition of various types of pellet binders. There are several types of pellet binders, including bentonite clays, lignosulfonates, and grain starch products, that result in firmer, more durable pellets able to withstand the rigors of mechanical feed handling systems.

3. Nutrient Requirements of Swine and Poultry

Numerous researchers at state and governmental research institutes have defined the requirements of swine and poultry for virtually all known nutrients. In addition, the nutrient composition of common ingredients has been determined. Through the use of a mathematical technique known as linear programming, aided by the use of high speed computers, poultry and swine nutritionists are able to formulate nutritionally balanced diets for all species of animals. As ingredient prices change as a result of supply and demand, diet composition can be changed almost instantly.

There is no best feed composition because animals thrive on diets composed of many different types of ingredients. Swine and poultry generally adapt readily and rapidly to changes in ingredient composition, as long as the diets provide adequate levels of essential nutrients. Tables 2–7 list information on the nutrient requirements of various types of swine and poultry.

Poultry can be grown on many diverse types of diets. Because of the high percentage of chickens grown under an integrated system, it is sometimes difficult to purchase small quantities of high quality feeds. Persons who sometimes utilize chickens for laboratory or research animals may require information regarding formulas that can be mixed from readily available ingredients. Three such formulas are given in Table 8. The first of these is a practical diet, composed primarily of corn and soybean meal and appropriate vitamin and mineral supplements. The second is a purified diet, based principally on isolated soybean protein and glucose. The third is a chemically defined diet, composed primarily of amino acids, glucose, and vitamin and mineral supplements. These diets are designed to allow adequate, but not necessarily optimal, growth of young chicks.

Table 2. **Nutrient Requirements of Broiler Chickens at Specific Ages,[a,b] Weeks**

Nutrient	0–3	3–6	6–8
metabolizable energy, kJ/g[c]	13.39	13.39	13.39
protein, %	23.0	20.0	18.0
arginine, %	1.25	1.10	1.00
glycine and serine, %	1.25	1.14	0.97
histidine, %	0.35	0.32	0.27
isoleucine, %	0.80	0.73	0.62
leucine, %	1.20	1.09	0.93
lysine, %	1.10	1.00	0.85
methionine and cystine, %	0.90	0.72	0.60
methionine, %	0.50	0.38	0.32
phenylalanine and tyrosine, %	1.34	1.22	1.04
phenylalanine, %	0.72	0.65	0.56
threonine, %	0.80	0.74	0.68
tryptophan, %	0.20	0.18	0.16
valine, %	0.90	0.82	0.70
linoleic acid, %	1.00	1.00	1.00
calcium, %	1.00	0.90	0.80
phosphorus, nonphytate %	0.45	0.35	0.30
potassium, %	0.30	0.30	0.30
sodium, %	0.20	0.15	0.12
chlorine, %	0.20	0.15	0.12
magnesium, mg/kg	600	600	600
manganese, mg/kg	60	60	60
zinc, mg/kg	40	40	40
iron, mg/kg	80	80	80
copper, mg/kg	8	8	8
iodine, mg/kg	0.35	0.35	0.35
selenium, mg/kg	0.15	0.15	0.15
vitamin A, IU/kg	1500	1500	1500
vitamin D, ICU/kg[d]	200	200	200
vitamin E, IU/kg	10	10	10
vitamin K, mg/kg	0.50	0.50	0.50
riboflavin, mg/kg	3.6	3.6	3.0
pantothenic acid, mg/kg	10	10	10
niacin, mg/kg	35	30	25
vitamin B_{12}, g/kg	0.01	0.01	0.007
choline, mg/kg	1300	1000	750
biotin, mg/kg	0.15	0.15	0.12
folacin, mg/kg	0.55	0.55	0.50
thiamin, mg/kg	1.80	1.80	1.80
pyridoxine, mg/kg	3.5	3.5	3.0

[a] NRC, 1994. Nutrient requirements of poultry, 9th rev. ed., National Academy Press, Washington, D.C.

[b] Ref. 5.

[c] To convert kJ to kcal, divide by 4.184.

[d] Requirements of poultry for vitamin D are expressed in international chick units (ICU), which are based on the activity of vitamin D_3 in chick bioassays.

Table 3. **Nutrient Requirements of Immature Leghorn-Type Chickens at Specific Ages,[a,b] Weeks**

Nutrient	0–6	6–12	12–18	18–first egg	
metabolizable energy, kJ/g[c]	11.92	11.92	12.13	12.13	
protein, %	18.00	16.00	15.00	17.00	14.5
arginine, %	1.00	0.83	0.67	0.75	
glycine and serine, %	0.70	0.58	0.47	0.53	
histidine, %	0.26	0.22	0.17	0.20	
isoleucine, %	0.60	0.50	0.40	0.45	
leucine, %	1.10	0.85	0.70	0.80	
lysine, %	0.85	0.60	0.45	0.52	
methionine, %	0.30	0.25	0.20	0.22	
methionine + cystine, %	0.62	0.52	0.42	0.47	
phenylalanine, %	0.54	0.45	0.36	0.40	
phenylalanine + tyrosine, %	1.00	0.83	0.67	0.75	
threonine, %	0.68	0.57	0.37	0.47	
tryptophan, %	0.17	0.14	0.11	0.12	
valine, %	0.62	0.52	0.41	0.46	
linoleic acid, %	1.00	1.00	1.00	1.00	
calcium, %	0.90	0.80	0.80	2.00	
phosphorus, nonphytate %	0.40	0.35	0.30	0.32	
potassium, %	0.25	0.25	0.25	0.25	
sodium, %	0.15	0.15	0.15	0.15	
chlorine, %	0.15	0.12	0.12	0.15	
magnesium, mg/kg	600	500	400	400	
manganese, mg/kg	60	30	30	30	
zinc, mg/kg	40	35	35	35	
iron, mg/kg	80	60	60	60	
copper, mg/kg	5.0	4.0	4.0	4.0	
iodine, mg/kg	0.35	0.35	0.35	0.35	
selenium, mg/kg	0.15	0.10	0.10	0.10	
vitamin A, IU/kg	1500	1500	1500	1500	
vitamin D, ICU/kg[d]	200	200	200	300	
vitamin E, IU/kg	10.0	5.0	5.0	5.0	
vitamin K, mg/kg	0.5	0.5	0.5	0.5	
riboflavin, mg/kg	3.6	1.8	1.8	2.2	
pantothenic acid, mg/kg	10.0	10.0	10.0	10.0	
niacin, mg/kg	27.0	11.0	11.0	11.0	
vitamin B_{12}, g/kg	0.009	0.003	0.003	0.004	
choline, mg/kg	1300	900	500	500	
biotin, mg/kg	0.15	0.10	0.10	0.10	
folacin, mg/kg	0.55	0.25	0.25	0.25	
thiamin, mg/kg	1.00	1.0	0.8	0.8	
pyridoxine, mg/kg	3.0	3.0	3.0	3.0	

[a]NRC, 1994. Nutrient requirements of poultry, 9th rev. ed., National Academy Press, Washington, D.C.

[b]Ref. 5.

[c]To convert kJ to kcal, divide by 4.184.

[d]Requirements of poultry for vitamin D are expressed in international chick units (ICU), which are based on the activity of vitamin D_3 in chick bioassays.

Table 4. **Nutrient Requirements of Leghorn-Type Laying Hens at Different Levels of Feed Intake (90% dry matter basis)**[a,b]

	Dietary concentrations Required at different feed Intakes (g/day)			Amount needed per hen daily (mg or IU) at 100 g daily feed intake
nutrient	80	100	120	
protein, %	18.8	15.0	12.5	15000
arginine, %	0.88	0.70	0.58	700
histidine %	0.21	0.17	0.14	170
isoleucine, %	0.81	0.65	0.54	650
leucine, %	1.03	0.82	0.68	820
lysine, %	0.86	0.69	0.58	690
methionine, %	0.38	0.30	0.25	300
methionine + cystine, %	0.73	0.58	0.48	580
phenylalanine, %	0.59	0.47	0.39	470
phenylalanine + tyrosine, %	1.04	0.83	0.69	830
threonine, %	0.59	0.47	0.39	470
tryptophan, %	0.20	0.16	0.13	160
valine, %	0.88	0.70	0.58	700
linoleic acid, %	1.25	1.0	0.83	1000
calcium, %	4.06	3.25	2.71	3250
chlorine, %	0.16	0.13	0.11	130
magnesium, mg	625	500	420	50
phosphorus, nonphytate %	0.31	0.25	0.21	250
potassium, %	0.19	0.15	0.13	150
sodium, %	0.19	0.15	0.13	150
copper, mg	?	?	?	?
iodine, mg	0.044	0.035	0.029	0.004
iron, mg	56	45	38	4.5
manganese, mg	25	20	17	2.0
selenium, mg	0.08	0.06	0.05	0.006
zinc, mg	44	35	29	3.5
vitamin A, IU	3750	3000	2500	300
vitamin D, ICU[c]	375	300	250	30
vitamin E, IU	6	5	4	0.5
vitamin K, mg	0.6	0.5	0.4	0.05
vitamin B_{12}, mg	0.004	0.004	0.004	0.0004
biotin, mg	0.13	0.1	0.08	0.01
choline, mg	1310	1050	875	105
folacin, mg	0.31	0.25	0.21	0.025
niacin, mg	12.5	10.0	8.3	1.0
pantothenic acid, mg	2.5	2.0	1.7	0.20
pyridoxine, mg	3.1	2.5	2.1	0.25
riboflavin, mg	3.1	2.5	2.1	0.25
thiamin, mg	0.88	0.70	0.60	0.07

[a] NRC, 1994. Nutrient requirements of poultry. 9th rev. ed. National Academy Press, Washington, D.C.

[b] Ref. 5.

[c] Requirements of poultry for vitamin D are expressed in international chick units (ICU), which are based on the activity of vitamin D_3 in chick bioassays.

Table 5. **Nutrient Requirements of Growing Turkeys at Specific Ages[a,b] Weeks**

Nutrient	0–4	4–8	8–12	12–16	16–20	20–24
metabolizable energy, kJ/g[c]	11.71	12.13	12.55	12.97	13.39	13.81
protein, %	28.0	26.0	22.0	19.0	16.5	14
arginine, %	1.6	1.4	1.1	0.9	0.75	0.6
glycine and serine, %	1.0	0.9	0.8	0.7	0.6	0.5
histidine, %	0.58	0.5	0.4	0.3	0.25	0.2
isoleucine, %	1.1	1.0	0.8	0.6	0.5	0.45
leucine, %	1.9	1.75	1.5	1.25	1.0	0.8
lysine, %	1.6	1.5	1.3	1.0	0.8	0.65
methionine, %	0.55	0.45	0.4	0.35	0.25	0.25
methionine + cystin, %	1.05	0.95	0.8	0.65	0.55	0.45
phenylalanine, %	1.0	0.9	0.8	0.7	0.6	0.5
phenylalanine + tyrosine, %	1.8	1.6	1.2	1.0	0.9	0.9
threonine, %	1.0	0.95	0.8	0.75	0.6	0.5
tryptophan, %	0.26	0.24	0.2	0.18	0.15	0.13
valine, %	1.2	1.1	0.9	0.8	0.7	0.6
linoleic acid, %	1.0	1.0	0.8	0.8	0.8	0.8
calcium, %	1.2	1.0	0.85	0.75	0.65	0.55
phosphorus, nonphytate %	0.6	0.5	0.42	0.38	0.32	0.28
potassium, %	0.7	0.6	0.5	0.5	0.4	0.4
sodium, %	0.17	0.15	0.12	0.12	0.12	0.12
chlorine, %	0.15	0.14	0.14	0.12	0.12	0.12
magnesium, mg/kg	500	500	500	500	500	500
zinc, mg/kg	70	65	50	40	40	40
iron, mg/kg	80	60	60	60	50	50
copper, mg/kg	8	8	6	6	6	6
iodine, mg/kg	0.4	0.4	0.4	0.4	0.4	0.4
selenium, mg/kg	0.2	0.2	0.2	0.2	0.2	0.2
vitamin A, IU/kg	5000	5000	5000	5000	5000	5000
vitamin D, ICU/kg[d]	1100	1100	1100	1100	1100	1100
vitamin E, IU/kg	12	12	10	10	10	10
vitamin K, mg/kg	1.75	1.5	1.0	0.75	0.75	0.50
vitamin B_{12}, mg	0.003	0.003	0.003	0.003	0.003	0.003
biotin, mg	0.25	0.2	0.125	0.125	0.100	0.10
chline, mg	1600	1400	1100	1100	950	800
folacin, mg	1.0	1.0	0.8	0.8	0.7	0.7
niacin, mg	60	60	50	50	40	40
pantothenic acid, mg	10	9.0	9.0	9.0	9.0	9.0
pyridoxine, mg	4.5	4.5	3.5	3.5	3.0	3.0
riboflavin, mg	4.0	3.6	3.0	3.0	2.5	2.5
thiamin, mg	2.0	2.0	2.0	2.0	2.0	2.0

[a] NRC, 1994. Nutrient requirements of poultry, 9th rev. ed., National Academy Press, Washington, D.C.

[b] Ref.5.

[c] To convert kJ to kcal, divide by 4.184.

[d] Requirements of poultry for vitamin D are expressed in international chick units (ICU), which are based on the activity of vitamin D_3 in chick bioassays.

Table 6. **Nutrient Requirements of Growing Swine Allowed Feed *Ad Libitum*[a,b]**

	Swine liveweight, kg				
Intake levels	1–5	5–10	10–20	20–50	50–110
expected weight gain, g/day	200	250	450	700	820
expected feed intake, g/day	250	460	950	1900	3110
	Nutrients				
metabolizable energy, kJ/g[c]	13.47	13.56	13.60	13.64	13.70
protein, %	24	20	18	15	13
arginine, %	0.60	0.50	0.40	0.25	0.10
histidine, %	0.36	0.31	0.25	0.22	0.18
isoleucine, %	0.76	0.65	0.53	0.46	0.38
leucine, %	1.00	0.85	0.70	0.60	0.50
lysine, %	1.40	1.15	0.95	0.75	0.60
methionine and cystine, %	0.68	0.58	0.48	0.41	0.34
phenylalanine and tyrosine, %	1.10	0.94	0.77	0.66	0.55
threonine, %	0.80	0.68	0.56	0.48	0.40
tryptophan, %	0.20	0.17	0.14	0.12	0.10
valine, %	0.80	0.68	0.56	0.48	0.40
linoleic acid, %	0.1	0.1	0.1	0.1	0.1
calcium, %	0.90	0.80	0.70	0.60	0.50
phosphorus, %					
total	*0.70*	*0.65*	*0.60*	*0.50*	*0.40*
available	0.55	0.40	0.32	0.23	0.15
sodium, %	0.10	0.10	0.10	0.10	0.10
chlorine, %	0.08	0.08	0.08	0.08	0.08
magnesium, %	0.04	0.04	0.04	0.04	0.04
potassium, %	0.30	0.28	0.26	0.23	0.17
copper, mg/kg	6.0	6.0	5.0	4.0	3.0
iodine, mg/kg	0.14	0.14	0.14	0.14	0.14
iron, mg/kg	100	100	80	60	40
manganese, mg/kg	4	4	3	2	2
selenium, mg/kg	0.3	0.3	0.25	0.15	0.1
zinc, mg/kg	100	100	80	60	50
vitamin A, IU/kg	2200	2200	1750	1300	1300
vitamin D, IU/kg	220	220	200	150	150
vitamin E, IU/kg	16	16	11	11	11
vitamin K, mg/kg	0.5	0.5	0.5	0.5	0.5
biotin, mg/kg	0.08	0.05	0.05	0.05	0.05
choline, g/kg	0.6	0.5	0.4	0.3	0.3
folacin, mg/kg	0.3	0.3	0.3	0.3	0.3
niacin, available, mg/kg	20	15	12.5	10	7
pantothenic acid, mg/kg	12	10	9	8	7
riboflavin, mg/kg	4	3.5	3	2.5	2
thiamin, mg/kg	1.5	1	1	1	1
pyridoxine, mg/kg	2	1.5	1.5	1	1
vitamin B_{12}, μg/kg	20	17.5	15	10	5

[a] Ref. 6.

[b] Ninety percent dry matter basis. Requirements based on the following diets: 1–5-kg pig diet includes 25–75% milk products; 5–10-kg pigs, a corn–soybean meal diet that includes 5–25% milk products; 10–110-kg pigs, a corn–soybean meal diet. In corn–soybean meal diets the corn and soybean meal contain 8.5 and 44% crude protein, respectively.

[c] To convert kJ to kcal, divide by 4.184.

Table 7. **Nutrient Requirements of Breeding and Lactating Swine**[a,b]

Nutrient	Breeding[c]	Lactating[d]
metabolizable energy, kJ/g[e]	13.43	13.43
protein, %	12	13
arginine, %	0.00	0.40
histidine, %	0.15	0.25
isoleucine, %	0.30	0.48
leucine, %	0.30	0.48
lysine, %	0.43	0.60
methionine and cystine, %	0.23	0.36
phenylalanine and tyrosine, %	0.45	0.70
threonine, %	0.30	0.43
tryptophan, %	0.09	0.12
valine, %	0.32	0.60
linoleic acid, %	0.1	0.1
calcium, %	0.75	0.75
phosphorus, %		
total	*0.60*	*0.60*
available	0.35	0.35
sodium, %	0.15	0.20
chlorine, %	0.12	0.16
magnesium, %	0.04	0.04
potassium, %	0.20	0.20
copper, mg/kg	5	5
iodine, mg/kg	0.14	0.14
iron, mg/kg	80	80
manganese, mg/kg	10	10
selenium, mg/kg	0.15	0.15
zinc, mg/kg	50	50
vitamin A, IU/kg	4000	2000
vitamin D, IU/kg	200	200
vitamin E, IU/kg	22	22
vitamin K, mg/kg	0.5	0.50
biotin, mg/kg	0.20	0.20
choline, g/kg	1.25	1.00
folacin, mg/kg	0.30	0.30
niacin, available, mg/kg	10	10
pantothenic acid, mg/kg	12	12
riboflavin, mg/kg	3.75	3.75
thiamin, mg/kg	1	1
pyridoxine, mg/kg	1	1
vitamin B_{12}, μg/kg	15	15

[a] Ref. 6.

[b] Requirements based on corn–soybean meal diets with typical feed intakes and performance levels. In corn–soybean meal diets, the corn and soybean meal contain 8.5 and 44% crude protein, respectively.

[c] Gilts, sows, and adult boars.

[d] Gilts and sows.

[e] To convert kJ to kcal, divide by 4.184.

Table 8. **Reference Diets for Growing Chickens**[a]

Ingredient	Practical	Purified[b]	Chemically defined[c,d]
ground yellow corn, g/kg	580		
soybean meal, 48% protein, g/kg	350		
isolated soybean protein, g/kg		250	
DL-methionine, g/kg	2.5	6	
glycine, g/kg		4	
corn oil, g/kg	30	40	50–150
cellulose, g/kg		30	30
choline chloride, 50%, g/kg	1.5	2.0	2.0
thiamin HCl, mg/kg	1.8	15.0	100.0
riboflavin, mg/kg	3.6	15.0	16.0
calcium pantothenate, mg/kg	10.0	20.0	20.0
niacin, mg/kg	25.0	50.0	100.0
pyridoxine HCl, mg/kg	3.0	6.0	6.0
folacin, mg/kg	0.55	6.0	4.0
biotin, mg/kg	0.15	0.6	0.6
vitamin B_{12}, μg/kg	10	20	20
p-aminobenzoic acid, mg/kg			2.0
ascorbic acid, mg/kg			250.0
vitamin A, IU/kg	1500	4500	10,000
vitamin D_3, ICU/kg[e]	400	4500	600
vitamin E, IU/kg	10	50	20
vitamin K, mg/kg	0.55	1.5	5.0
ethoxyquin, mg/kg	125	100	125
iodized salt, g/kg	5		
NaCl, g/kg		6	8.8
$CaCO_3$, g/kg	10	14.8	3
$CaHPO_4 \cdot 2H_2O$, g/kg	20	20.7	
$MgSO_4 \cdot H_2O$, g/kg		10	9
K_2HPO_4, g/kg		10	9
$NaHCO_3$, g/kg			15
$MnSO_4 \cdot 5H_2O$, mg/kg	170	350	650
$ZnSO_4 \cdot H_2O$, mg/kg	110		
$ZnCO_3$, mg/kg		150	100
$Fe_2(SO_4)_3 \cdot 7H_2O$, mg/kg	500		
ferric citrate pentahydrate, mg/kg	500		500
$CuSO_4 \cdot 5H_2O$, mg/kg	16	30	20
Na_2SeO_3, mg/kg	0.2	0.2	0.2
glucose or starch,[f] kg	1	1	1

[a] Ref.5.

[b] Also contains 1 g/kg KCl, 2 mg/kg KIO_2, and 1.7 mg/kg $CoCl_2$.

[c] Based on an amino acid mixture: 11.5 g L-arginine HCl, 4.5 g L-histidine $HCl \cdot H_2O$, 11.4 g L-lysine HCl, 4.5 g L-tyrosine, 1.5 g L-tryptophan, 5 g L-phenylalanine, 3.5 g DL-methionine, 3.5 g L-cystine, 6.5 g L-threonine, 10 g L-leucine, 6 g L-isoleucine, 6.9 g L-valine, 6 g glycine, 4 g L-proline, and 120 g L-glutamic acid.

[d] Also contains 28 g/kg $Ca_3(PO_4)_2$; 40 mg/kg KI; 1 mg/kg $CoSO_4 \cdot 7H_2O$; 9 mg/kg H_3BO_3; and 9 mg/kg $Na_2MoO_4 \cdot 2H_2O$.

[e] ICU = international chick units.

[f] Value given is maximum.

4. Feed Additives for Nonruminants

Feed additives are common to swine and poultry feeds for a number of purposes. Antibiotics (qv), used to promote growth and improve feed utilization, are poorly digestible and function primarily by controlling the bacterial flora of the intestinal tract. Antibiotics fed to animals for this purpose generally are not used for human antibiotic therapy. Other antibiotics, used for disease therapy, are generally injected or are absorbed into the body tissues where they are effective against the disease-causing organisms. Other feed additives include antioxidants (qv) to protect feeds against oxidative rancidity, mold inhibitors to prevent development of potentially toxic mold products, anticoccidial compounds that protect chickens against this severe parasitic disease, anthelmintics, and other types of growth promoters (see GROWTH REGULATORS).

Feed additives fall into two general categories, ie, medicated and generally recognized as safe (GRAS). Medicated feed additives consist of products where usage level and purpose are strictly regulated by the U.S. Food and Drug Administration (FDA). Feed manufacturers who utilize medicated feed additives must first register as a drug establishment with the FDA. Individuals mixing feed for their own animals are subject to the same rules as commercial feed mills. Annual registration is required and once the mill is registered it must obtain approval from the FDA for each of the medicated feed additives used. The feed manufacturer must determine whether each animal drug used has been approved by the FDA for its intended use and what further approvals, if any, are needed.

The various FDA approved (~1992) feed additives for chicken, turkey, and swine, grouped according to their usage, are as follows:

Official information concerning FDA approval of antibiotics and other drugs is available in the *Code of Federal Regulations* (7). This document is revised at least once per year and updated in individual issues of the *Federal Register*. These two publications are utilized together to determine the latest status of any given product. The *Code of Federal Regulations* is published in six parts: animal feeds, drugs, and related products are included (7).

An effective and less expensive way to maintain information regarding the status of approved feed additives for animal feeds is to subscribe to the *Feed Additive Compendium,* published yearly and updated monthly (8). This publication gives detailed information on specific antimicrobial agents, levels of usage, sources of product, and legal requirements for use in the United States. Although effective as a source of information on approved feed additives, it cannot be considered as a legal authority.

There are a large number of feed additive products classified as GRAS. These are products that have been considered by a group of qualified experts to be safe for the intended use in animal feeds; no permission or registration is required for use at recommended levels based on scientific procedures or experience in common use in feed. There must be reasonable evidence to support the safety of such products. Some restrictions are placed on quantity of some products, such as selenium and ethoxyquin. GRAS products include a wide range of materials, ranging from ammoniated cottonseed meal to xanthan gum. A list of all GRAS substances for animal feeds is available (7).

The GRAS listing does not include widely used, historical products such as grains, sugar, salt, etc. In general, feed ingredients listed in the *American Association of Feed Control Officials* (AAFCO) official publication are considered in the GRAS category (9).

A number of products designated GRAS are being scrutinized by the FDA because of advertisements and claims made by producers or manufacturers of these products. Statements that indicate that feeding such products improve animal performance may require substantive data to support such claims in the future.

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