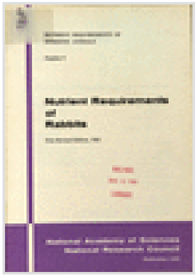

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NUTRIENT REQUIREMENTS OF DOMESTIC ANIMALS

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NUTRIENT REQUIREMENTS OF
DOMESTIC ANIMALS

Number 9

Nutrient Requirements of Rabbits

Revised 1966

A Report of the

SUBCOMMITTEE ON RABBIT NUTRITION
NRC COMMITTEE ON ANIMAL NUTRITION
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FOREWORD

NUTRIENT REQUIREMENTS OF RABBITS was compiled originally in 1954 by the Subcommittee on Rabbit Nutrition of the Committee on Animal Nutrition of the National Academy of Sciences—National Research Council. It is the ninth in a series of reports on nutrient requirements of domestic animals issued by the Academy—Research Council. The members of the Subcommittee that prepared the report are specialists in basic and applied animal nutrition, with special experience in rabbit nutrition based on research and on study of practical field problems. This report presents the most reliable nutrient standards possible with the information available to the Subcommittee.

The work of the Subcommittee is, of course, not ended. Whenever substantial new experimental evidence is reported, NUTRIENT REQUIREMENTS OF RABBITS will be revised and enlarged to bring it up to date.

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SUBCOMMITTEE ON RABBIT NUTRITION

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DEVELOPMENT OF NUTRIENT REQUIREMENTS

The domestic rabbit is descended from the wild rabbit found in the Mediterranean countries and was introduced into England in the late eleventh or early twelfth century. The different breeds of the modern domestic rabbit have been evolved since the eighteenth century. There are now several hundred different varieties throughout the world, varying in type of coat, in color, and in size. The American Rabbit Breeders Association lists standards for 28 different breeds and approximately 77 varieties of these breeds. Domestic rabbits are raised for fur, meat, laboratory purposes, or as pets. Meat production is the most important commercial aspect and will be emphasized in this bulletin. Only a relatively few breeds, such as the New Zealand White, Californian, American, Chinchilla, and Flemish Giant, are raised strictly for meat production. Of these, the New Zealand White and Californian are the most popular because they have white pelts, which are preferred by furriers. The skins, used for a variety of purposes by the industry, are an important by-product of meat production. Wool production from the Angora breeds is a popular phase of the industry in a few sections of the United States. Recommendations concerning specific nutrient requirements for rabbit-wool production are not possible because the necessary information is lacking. A growing phase of the rabbit industry is supplying rabbits for laboratory purposes. Rabbits are used in almost every aspect of medical and biological research, and many breeders gain a comfortable income from this source. In North America and England, the breeding of rabbits for show is a very popular hobby. The segment of the industry involving the fancier and hobbyist will be referred to in this bulletin only indirectly.

The raising of rabbits for meat received special impetus during World War II and, though peak years of production were during that period, it is estimated that between 25 and 30 million pounds of domestic rabbit meat are still consumed annually in the United States. Southern California is the leading production area.

The domestic rabbit is primarily herbivorous and will eat most types of greens, grains, and hay. Therefore, in rabbit husbandry, the rations provided consist almost entirely of ingredients from plant sources. Though some rabbit raisers still utilize home-grown feeds and mix their own rations, there is an increasing tendency to utilize commercially prepared rabbit feeds in the form of pellets.

Rabbits habitually practice coprophagy, sometimes referred to as pseudorumination. It refers to consumption of soft fecal pellets directly from the anus. The history of the phenomenon and its relevance to rabbit nutrition is well reviewed by Thompson and

Worden (1956). These workers found that coprophagy was usually practiced by domestic rabbits as young as three weeks of age at night and by wild rabbits while they were in the burrow during the daytime. It is generally assumed that coprophagy, in conjunction with fermentation in the large intestine, supplies necessary amounts of most B vitamins, probably provides insurance against an essential amino-acid deficiency, and may permit further digestion of fiber and other nutrients by a second passage through the digestive tract.

This report presents information on requirements, effects of deficiencies, and composition of feeds commonly fed to rabbits. Since rabbit nutrition is still little understood, the values given are subject to revision as additional or more exact data become available. To make maximum use of published data in preparing the tables of nutrient requirements, some calculations and interpolations were necessary. The values arrived at by the Subcommittee preparing this report, however, were not intentionally increased because it is believed that the original findings represent allowances that are adequate and permit maintenance of normal health and productivity of animals. The Subcommittee also recognizes that differences in breeds, strains, geography, and feeds available may influence the composition of rations, and that feed manufacturers and rabbit raisers may find it desirable to increase the concentration of labile nutrients whenever transportation and storage conditions may cause some deterioration in nutrients.

SPECIFIC NUTRIENT REQUIREMENTS

Sufficient new data have accumulated since the first publication of this report (1954) to warrant a revision. The greatest change involves the protein requirements that have generally been found to be significantly less than those previously recommended. The requirements of two additional mineral elements have been added. It is regrettable that vitamins have received so little attention during the last 10 years. The same condition prevails for energy requirements, with the result that we must resort to basing recommendations on observations rather than experimentation.

TOTAL DIGESTIBLE NUTRIENTS

The total digestible-nutrient (TDN) recommendations in Tables 1 and 2 are based on the results of many observations and feeding trials at the U.S. Rabbit Experiment Station, Fontana, California, and at the Department of Animals Husbandry, Cornell University. The TDN values of these diets were estimated from average figures obtained by Voris *et al.* (84) and listed in Table 4. In converting recommendations from one weight class to another, body weight to the three-fourths power was used, as expressed in Kleiber's (44) general formula for metabolic rate, $M = 70W^{3/4}$. The recommendations thus represent actual observed intakes, with adjustments to conform with theory.

PROTEIN

In a series of experiments, Smith *et al.* (4) have determined that the total crude protein requirement for growing and fattening New Zealand White rabbits approximates 15 per cent of the air-dried diet. Unpublished data of Donefer (2) support this figure and present further evidence that the very young rabbit (3-6 weeks of age) has a requirement somewhat higher than this, perhaps 18 per cent. For lactating does, unpublished data of Casady and Lofgreen (67) indicate that the requirement is about 17 per cent of total crude protein. These data were converted to digestible protein using an average figure of 75 per cent digestibility.

The sensitivity of rabbits to quality of protein is unknown. The fact that rabbits have been successfully raised on relatively simple mixtures of plant products indicates that the protein quality may not be of great importance. Some contrary evidence is found in the report of Olcese and Pearson (3), who were unable to show that rabbits utilize urea nitrogen even through the well-known practice of coprophagy was not prevented.

FAT

No specific fat requirements have been established for rabbits. Most commercial feed tags show the fat content as not less than 2 to

TABLE 1. DAILY NUTRIENT REQUIREMENTS OF RABBITS
(All feeds or rations are based on air-dry weights)

Body Weight Lb	Expected Daily Gain Lb	Total Feed per Animal Lb	Total Digestible Nutrients per Animal Lb	Total Protein per Animal Lb	Digestible Protein per Animal Lb
NORMAL GROWTH, DOES OR BUCKS. AVERAGE 6.5 LB WEIGHT					
4 to 9	—	0.32	0.19	0.05	0.03
NORMAL GROWTH AND FATTENING, DOES OR BUCKS					
4		0.25	0.16	0.04	0.03
5	Av.	0.30	0.19	0.05	0.04
6	0.07	0.34	0.22	0.05	0.04
7		0.38	0.25	0.06	0.05
MAINTENANCE, DOES OR BUCKS					
5	—	0.20	0.11	0.03	0.02
10	—	0.33	0.18	0.04	0.03
15	—	0.45	0.25	0.05	0.04
PREGNANT DOES					
5	—	0.25	0.15	0.04	0.03
10	—	0.41	0.24	0.06	0.05
15	—	0.56	0.33	0.08	0.06

3 per cent, and the U.S. Rabbit Experiment Station has been recommending 2 to 5.5 per cent (59). Thacker (60) fed rations containing 5, 10, 15, 20, and 25 per cent fat in the form of vegetable oils, and showed that those containing 10 to 25 per cent fat produced greater body gains than rations containing 5 per cent. Palatability and efficient feed utilization, as indicated by weight gains per unit of feed intake, increased as the fat content of the diet increased. Digestibility of dry matter, ether-extractable matter, and crude protein was not affected by high fat levels. It would seem that the rabbit could benefit from higher levels of fat than are now being generally fed.

MINERALS

It is probable that rabbits require the same mineral elements as other animals, with the exception of cobalt (58). However, estimated requirements are available only for manganese, magnesium, potassium, and phosphorus.

Smith and Ellis (53, 54), using a basal diet of milk, found that 0.3 mg of manganese per rabbit per day prevented obvious symptoms of manganese deficiency in mature animals. Growth requirements were higher, approximating 1.0 mg per rabbit per day.

Kunkel and Pearson (50), from their data on New Zealand White rabbits fed purified diets, estimated the magnesium requirement to be between 30 and 40 mg per 100 g of diet.

Hove and Herndon (48) found rabbits to require at least 0.6 per cent of potassium in a purified diet—a figure that is considerably higher than for other animals so far studied.

Mathieu and Smith (52) studied New Zealand White rabbits on semipurified diets and found the phosphorus requirement to approximate a dietary level of 0.22 per cent, a figure that is well in line with other comparable animals.

VITAMINS

Although rabbit dietary requirements have been recognized for many of the known vitamins, the extent of the requirement has been estimated for only a few.

Phillips and Bohstedt (35) demonstrated that 50 μg of carotene (provitamin A) per kg of body weight prevented symptoms of vitamin A deficiency and permitted normal growth and reproduction. Massive doses of carotene or vitamin A have been used by others to obtain rapid recovery from the deficiency state (27, 29).

Although the quantitative requirement for vitamin D is not known, symptoms of rickets have been produced with diets deficient in this vitamin (10,28). Jarl (20) fed rabbits a diet low in vitamin D with a narrow calcium–phosphorus ratio, and demonstrated that interference with calcification was only temporary, since by 8 to 12 weeks of age bone growth equaled that of control rabbits fed supplemental vitamin D.

There is general agreement that the daily vitamin E (α-tocopherol) requirement is about 1 mg per kg of body weight (8, 14, 17, 25). Diehl (6, 7) demonstrated a one-third decrease in body-tocopherol levels in rabbits showing liver lesions due to coccidiosis infections when compared to noninfected animals. He has suggested that, due to the widespread occurrence of this disease, many rabbits used in laboratory studies may be in a state of hypovitaminosis E.

Limited studies indicate that dietary supplies of vitamin K are required for normal reproduction but not for growth (13, 30).

There is evidence that requirements for the various B vitamins are partially or completely satisfied through the habitual practice by rabbits of coprophagy. This practice makes possible the utilization of vitamins synthesized in the lower intestinal tract by microbes.

Olcese *et al.* (33) found that rabbits grew normally when fed pantothenic-acid-deficient

TABLE 2. NUTRIENT REQUIREMENTS OF RABBITS IN PERCENTAGES OF THE TOTAL RATION (All feeds or rations are based on air-dry weights)

Body Weight Lb	Expected Daily Gain Lb	Total Daily Feed[1]	Total Digestible Nutrients %	Total Protein %	Digestible Protein %
NORMAL GROWTH, DOES OR BUCKS. AVERAGE 6.5 LB					
4 to 9	—	5.8	60	15	11
NORMAL GROWTH AND FATTENING, DOES OR BUCKS					
4		6.2	65	16	12
5	Av.	6.0	65	16	12
6	0.07	5.7	65	16	12
7		5.4	65	16	12
MAINTENANCE, DOES OR BUCKS					
5	—	4.0	55	12	9
10	—	3.3	55	12	9
15	—	3.0	55	12	9
PREGNANT DOES					
5	—	5.0	58	15	11
10	—	4.1	58	15	11
15	—	3.7	58	15	11
LACTATING DOE AND LITTER OF 7					
5	—	—	70	17	13
10	—	—	70	17	13
15	—	—	70	17	13

[1] Percentage of live weight.

and riboflavin-deficient diets and demonstrated that these vitamins were excreted in amounts greatly in excess of dietary intakes. The intestinal synthesis of biotin and folic acid was also demonstrated.

While others of the B vitamin group are synthesized by the rabbit, it has been shown that the amounts so produced are not adequate in all cases to meet the requirements of the animal. Even though substantial synthesis of niacin occurs in rabbits on diets deficient in this vitamin (21, 34), marked growth responses have been obtained with dietary supplements of up to 11 mg per kg of body weight (39, 40). Niacin can be synthesized from its precursor tryptophan, as shown by the growth response obtained when the amino acid was fed to niacin-deficient rabbits (21, 40).

Hove and Herndon (18) prevented the appearance of vitamin B_6 (pyridoxine) deficiency symptoms by feeding 39 μg daily or 1 μg per g of diet of this vitamin.

Choline-deficiency symptoms were prevented when a level of 0.12 per cent choline chloride was added to the diet (16, 17).

Although common rabbit diets are practically devoid of vitamin B_{12}, a large urinary and fecal excretion of this vitamin has been demonstrated, illustrating the role of microbial synthesis of this vitamin in the intestinal tract (21, 37). Simnett and Spray (38) have shown that vitamin B_{12} serum, fecal, and urinary levels are influenced by the nature of the diet, particularly its content of cobalt, a trace element required for the synthesis of the vitamin.

In regard to the vitamin C requirements, the evidence to date indicates that the rabbit does not require a dietary source of this vitamin. Harris *et al.* (11) demonstrated that young rabbits kept for periods of up to 25 weeks on a diet without vitamin C gained weight at a rate similar to control rabbits receiving the vitamin, and continued to excrete considerable amounts of vitamin C in their urine. This has confirmed earlier observations of Nelson *et al.* (32) and Hogan and Ritchie (12).

SYMPTOMS OF NUTRITIONAL DEFICIENCIES

Despite the fact that rabbits have long been useful experimental animals, complete descriptions of their various nutritional deficiencies are limited. Observations have frequently been recorded in trade magazines, but supporting data are usually insufficient to be considered conclusive.

The following discussion emphasizes frank symptoms of inadequacies in nutrients, observed for the most part on simplified or purified experimental diets. From the standpoint of practical rabbit production, such clear-cut symptoms are seldom encountered. Rather, deficiencies as they actually exist are usually of the submarginal type that, because of the lack of well-developed specific symptoms, are much more difficult to diagnose.

ENERGY

Since no specific energy requirements have been established for the rabbit, symptoms of energy deficiency are difficult to define. Feeding of low-energy rations (high in roughage content) during periods of fattening, reproduction, or lactation may result in this deficiency as characterized by retarded growth and failure to reproduce maximally. These same effects, however, can be caused by a number of factors, many of them not of nutritional origin. Barboreck (41) indicated that changes in the energy density of rabbit diets were not entirely reflected in changes of the rate of gain. In Barboreck's study, the rabbits apparently increased their feed consumption in order to satisfy energy and/or other nutritional requirements when fed low-energy feeds. The stock diet in use at the U.S. Rabbit Experiment Station, evolved after many years of experimentation, supplies approximately 550 kcal per lb of feed and has proved adequate. Diets prepared by commercial milling companies, especially in the Southern California area, generally supply between 500 and 600 kcal per lb and have proved to be satisfactory for commercial fryer production. With reference to the metabolic formula of Lee (45) and Kleiber (44), these values should be sufficient in terms of total productive energy.

MINERALS

The effects of phosphorus deprivation in rabbits were described by Mathieu and Smith (52), and they are similar to those described for other animals—decreased rates of gain, subnormal values for blood phosphorus, bone ash, bone-breaking strength, and others. Calcium deficiency has so far been studied only to a limited extent. Swan and Salit (57) reported an opacity of the eye lens, tetany, and a decreased calcium level in the blood. In contrast to most species, the calcium in the blood of rabbits seems to reflect dietary intakes rather easily.

It is generally assumed that rabbits need a supplemental source of sodium since their diets are made up so largely of sodium-deficient plant feeds, but this plausible inference has not yet been supported by research observations.

The lack of adequate iron in the diet results in anemia in rabbits, as it does in other species. This has been demonstrated by several workers as far back as 1900. Smith *et al.* (56) showed that this anemia was microcytic and hypochromic in type.

A deficiency of copper also results in an anemia in rabbits (47) as well as other symptoms (53, 54) such as graying and loss of the hair.

The symptoms of a manganese deficit have been described in some detail (46, 53–55). The most obvious is a maldevelopment of the skeletal system—crooked legs, brittle bones, and a decreased weight, density, length, and ash content of the bones.

Kunkel and Pearson (50) have characterized magnesium deficiency as poor growth and hyperexcitability leading to convulsions and death.

Hove and Herndon (48) showed that rabbits develop a muscular dystrophy when fed potassium-deficient diets, and that this dystrophy is similar to that caused by deficiencies of vitamin E and choline.

VITAMINS

Symptoms of vitamin A deficiency in rabbits are similar to those described for other animals and include retarded growth, neural lesions, ataxia and spastic paralysis, xerophthalmia, and impaired reproduction (22, 23, 29, 31, 35). In addition Lamming *et al.* (23) demonstrated a high incidence of hydrocephalus with stenosis of the cerebral aqueduct among young rabbits reared by females maintained on low-carotene diets for a period of 14 weeks before mating.

Rickets has been produced in rabbits by feeding them diets deficient in vitamin D and high in calcium (10, 20, 26).

Muscular dystrophy in rabbits, or cod-liver-oil injury, as it was referred to in early studies (9, 26), is today recognized as being primarily caused by a deficiency of vitamin E in this species. Symptoms of this syndrome include degeneration of skeletal and cardiac muscles, paralysis, and a fatty liver (5). That muscular dystrophy may not be due to simple vitamin E deficiency is indicated in studies in which deficiencies of choline (15) or potassium (48) have been implicated. Procter *et al.* (36) have produced muscular dystrophy in young rabbits fed a diet high in torula yeast which was not prevented by supplements of either α-tocopherol or selenium.

Moore *et al.* (30) fed a diet deficient in vitamin K to pregnant rabbits and demonstrated placental hemorrhage and abortion.

Dietary deficiencies of niacin have resulted in a pronounced loss of appetite, followed by emaciation and diarrhea (39).

Vitamin B_6 (pyridoxine) deficiency, as reported by Hove and Herndon (18), is characterized by decreased growth rate, and dermal and neurological symptoms that are similar to those observed in deficient rats and pigs and include acrodynia, convulsions, and sudden paralytic collapse.

The choline-deficiency syndrome in rabbits has been described as retarded growth, fatty and cirrhotic liver, and necrosis of kidney tubules (16, 17). A progressive muscular dystrophy is reported in rabbits fed a choline-deficient diet for more than 70 days (15).

A deficiency of biotin, characterized by loss of hair and dermatitis, occurs in those instances in which raw egg white is fed over a period of time (24).

EXAMPLES OF ADEQUATE RATIONS

Rabbits consume many kinds of feed satisfactorily. The feeds selected for use will be determined by availability, cost, and quality.

The high-energy concentrate feeds consist of whole grains such as oats, wheat, corn, grain sorghums, and barley and their milled by-products such as wheat bran, mill run, middlings, and red dog flour. These may be fed whole or may be coarsely ground and fed as a meal or in pelleted mixtures. Hard grains such as flint corn should be ground to avoid extensive waste.

Protein supplements include by-product feeds high in protein, such as peanut, linseed, soybean, cotton seed, hempseed, and sesame meals. These plant-protein supplements may be substituted for each other, so far as we know, on an equivalent protein unit basis in the diet. If cottonseed meal is used, it should be degossypolized and incorporated in the ration at a level not to exceed 5 to 7 per cent (67). While the extracted meals are excellent feeds, the original oil-rich seeds, such as whole peanuts and soybeans, are unpalatable. If they are included in the amounts required to balance the ration with respect to protein, the animals may fail to consume the ration satisfactorily.

Legume hays are superior to grass hays largely because they contain more protein and calcium and generally are more palatable. In most sections, alfalfa hay is the preferred roughage, but other legume hays such as the clovers, lespedeza, cowpea, vetch, and peanut are also satisfactory and may be substituted. All should be fine stemmed, leafy, of good green color, and as free of molds as possible.

The grass hays such as timothy, Johnson grass, prairie grass, Sudan grass, Dallis grass, Rhodes grass, and Bermuda grass ordinarily contain considerably less protein than the legume hays and, hence, are generally less satisfactory feeds for rabbits. Even when this difference is balanced by larger additions of protein supplements, the combination is less palatable than legume hays, especially if the grass has not been cut at an early stage of maturity.

Green feeds, including grass clippings, discarded leaves of vegetables, some weeds, and the cereal grasses, are succulent, palatable feeds. Because of their high water content they are bulky feeds and, on a dry-matter basis, contain more fiber than the concentrates. This, combined with the expense of harvesting, suggests that they be used by the commercial grower only as an appetizing supplement. In the operations of the small grower, in which time is of little consequence, they may form the bulk of the roughage allotment. Root crops are excellent succulent feeds, generally high in water but low in fiber. They are so relished that, unless their intake by young rabbits is limited, the animals will fail to eat a sufficient quantity of other feeds to balance the diet and will not make proper

TABLE 3. EXAMPLES OF ADEQUATE DIETS[1]

Ingredients	% of Total Diet
NORMAL GROWTH 4 TO 9 LB, AVERAGE 6.5 LB	
Alfalfa hay	60
Corn, grain	22
Barley, grain	15
Soybean meal	3
NORMAL GROWTH AND FATTENING 4 LB INITIAL WEIGHT; 8 LB FINAL WEIGHT[2]	
Alfalfa hay	40
Wheat bran	5
Barley, grain	32
Oats, grain	18
Soybean meal	5
MAINTENANCE, DOES AND BUCKS, AVERAGE 10 LB WEIGHT	
Alfalfa hay	70
Oats, grain	20
Wheat, grain	10
PREGNANT DOES, AVERAGE 10 LB WEIGHT	
Clover hay	50
Oats, grain	44
Soybean meal	6
LACTATING DOES, 10 LB AVERAGE WEIGHT; LITTER OF 7	
Alfalfa hay	40
Wheat, grain	25
Sorghum, grain	25
Soybean meal	10

[1] To each of the diets, added 0.5% salt or iodized salt if in an iodine-deficient region.
[2] May also be appropriate for pregnant and lactating does.

weight gains or achieve a desirable finish.

Miscellaneous feeds include a variety of ingredients that are of little interest to commercial growers but of great interest to small operators. Most table and kitchen wastes, except meat, fats, or spoiled foods, are acceptable. Milk and its by-products can be used if they are not too costly. Milk, however, contains 87 per cent water, and this must be kept in mind when substituting it for other feeds.

In practice, salt is generally added to the ration at a level of 0.5 per cent or provided ad libitum by means of a salt block. The example rations in Table 3 are adequate in mineral elements other than salt, so far as we know.

Since the great majority of rabbit breeders, including those raising rabbits in medical and biological laboratory colonies, use commercially prepared pelleted feeds, the rations in Table 3 are formulated on the basis of suitability for pelleting. They are also adapted to meet the TDN and digestible-protein requirements of Tables 1 and 2. The diets listed for normal growth and fattening are similar to those routinely used at the U. S. Rabbit Experiment Station and have proved adequate for full feeding of pregnant and lactating does.

Certain feeds are of interest because of their detrimental effects. There is evidence (74) that cottonseed meal may have a cumulative toxic effect, and more research is needed to properly evaluate its use in rabbit diets. There have been indications that large amounts of soybean hay may interfere with reproduction in rabbits (51, 65, 66, 75, 78). It also has been demonstrated that the feeding of large amounts of cabbage produces goiter in rabbits (63, 68, 85, 87). Other feeds that may not be acceptable or that may be toxic are summarized by Aitken and Wilson (62).

SELF FEEDING VERSUS HAND FEEDING

Feed may be placed once a day in standard rabbit-feed crocks or troughs. This is called hand feeding. Or a quantity of feed may be placed in feed hoppers from which the rabbit may feed at will. Such rabbits are said to be self-fed, or hopper-fed. Full feeding by hand produces about the same results as hopper feeding, provided the animals are fed all they will consume each day. In addition to rapid growth, full feeding usually increases the efficiency of weight gains (82). Full feeding is satisfactory for pregnant does, does nursing litters, and rabbits being fattened for market.

For herd bucks, dry does, and young breeding stock, restricted feeding is recommended in order to prevent the animals from becoming too fat. If herd bucks, dry does, and young breeding stock are full-fed, they may be maintained on a high-quality hay pellet alone, on unpelleted hay plus several ounces of a grain–protein mixture, or on an all-grain pellet, several times each week. It is important that herd bucks, dry does, and young breeding stock be kept in good physical condition and not allowed to become too fat.

SPECIAL FEEDING

PURIFIED RATIONS

Although a completely purified diet that will support maximal growth of rabbits has not been developed, diets have been described in the literature that support limited levels of growth as well as reproduction and lactation. Hogan and Ritchie (12) have reviewed early attempts to develop purified diets. Hogan and Hamilton (13) described a purified diet that was adequate for reproduction and lactation as well as growth. Wooley and Sebrell (39) have described a purified diet supplemented only with pure vitamin preparations. Nearly normal growth was obtained for a limited period of time when this diet was fed. Kunkel and Pearson (50) used a highly purified diet and found that the addition of all vitamins then known would not give as rapid growth as was obtained when a 4 per cent liver concentrate was added to the ration. Hove and Herndon (19) reported studies concerned with improving growth performance on purified diets containing casein as the source of protein. Supplementation of casein with several amino acids resulted in an average growth rate of 24 g per day, as compared to 34 g per day obtained when a commercial rabbit ration was fed.

ROUGHAGES ALONE

Maximal growth rates cannot be obtained when rabbits are fed a diet consisting solely of roughages. Crampton and Finlayson (69) obtained a twofold to fourfold increase in weight gains when alfalfa meal plus oats and linseed meal were fed compared to an exclusive diet of dried grass. Crampton and Forshaw (43) observed a large increase in average daily gain when starch was added to a dried-grass diet and concluded that lack of available energy was one of the factors limiting the growth of young rabbits fed all-roughage diets. Rendig (80) reported slow growth of rabbits fed only alfalfa hay supplemented with salt. Satisfactory reproduction and lactation were obtained when 20 per cent of the diet consisted of a sugar supplement. In Egypt, Ghoneim *et al.* (71) obtained an average growth rate of 64 g per week when young rabbits were fed solely clover hay for a 9-week period. Using the degree of feed conversion obtained and Egyptian feed costs, he concluded that even on an all-hay diet rabbits appeared to produce meat at a lower cost than native ducks and geese. High-quality alfalfa pellets or coarse-ground crumbles have been used successfully in raising young (junior) rabbits and maintaining dry does and herd bucks at the U.S. Rabbit Experiment Station.

Rabbits have been used to assay the nutritive value of forages. Crampton *et al.* (70) compared the relative ability of rabbits and steers to digest pasture herbage and found that, in general, rabbits digest such diets less completely, with no apparent consistent trend between the two species in the case of crude-fiber or cellulose digestion. Adolph *et al.* (61) tested the nutritive value of alfalfa hay, using rabbits weighing between 1.2 and 1.3 kg. They reported that the rabbits maintained body weight within 0.2 kg over a 3-month period when fed solely the ground alfalfa hays. On the other hand, Richards *et al.* (81) reported that rabbits "almost invariably lost flesh while on an all-forage ration."

PELLETED FEEDS

An all-grain pellet usually contains cereal grains, their milled by-products, protein supplement, and salt. A complete pellet may consist of ground cereal grains, their milled by-products, protein supplement, salt, and a good-quality ground hay. The usual proportions in complete pellets are 50 to 60 per cent concentrates and 40 to 50 per cent hay, with the 40 to 60 per cent proportion preferred for use during the lactation period. Commercial pellets may contain many other ingredients.

Pellets should be 3⁄16 in. or less in diameter and about 1⁄8 in. long; if they are too long, there will be considerable waste by young rabbits.

AVERAGE COMPOSITION AND DIGESTIBLE NUTRIENTS OF SELECTED FEEDS

Table 4 shows the total digestible-nutrient and digestible-protein values of some feeds commonly used for rabbits. These values were obtained by using the feed-composition values given by Morrison (79) and the digestion coefficients for rabbits obtained by Voris *et al.* (84). In general, the TDN values of the roughages are lower than those obtained for ruminants. This is in accord with the findings of Schurch (84) and others that rabbits are less efficient than ruminants in digesting fiber. Most values for digestible protein and the TDN for concentrate feeds agree approximately with the average values given by Morrison. In a few cases, such as soybean seed, the value obtained is considerably higher than that given by Morrison. The Voris digestion coefficients were compared with values obtained for rabbits by others (64, 77, 83, 86) and were found to agree quite closely.

TABLE 4. PARTIAL COMPOSITION OF FEEDS COMMONLY INCLUDED IN RABBIT DIETS[1]
(All data are on an as-fed basis)

Feed	Dry Matter	PROTEIN Crude	PROTEIN Digestible	ENERGY Gross	ENERGY Digestible	TDN	Calcium	Phosphorus	Carotene
	%	%	%	kcal/lb	kcal/lb	%	%	%	mg/lb
Concentrates									
Barley grain	89	11.7	10	1,760	1,450	70	0.08	0.42	0.18
Beet pulp, dried	91	9.1	4	1,737	1,374	70	0.68	0.10	0.1
Bread, dried	96	15.8	15	1,919	1,900	100	—	—	—
Brewers' grains, dried	92	25.9	22	2,236	1,342	58	0.27	0.50	—
Buckwheat grain	85	10.4	7	1,746	1,329	70	—	—	—
Corn, dent, gr. no. 2	89	8.9	7	1,805	1,661	82	0.02	0.31	0.8
Cottonseed meal, solvent	91	41.6	32	—	1,320	66	0.15	1.10	—
Linseed meal, expeller	91	35.3	31	—	1,400	70	0.44	0.89	0.14
Milk, cows'	12	3.1	3	327	298	25	—	—	—
Milk, dehydrated	94	35.2	26	—	—	117	0.89	0.68	3.2
Oats, grain	89	11.8	9	1,896	1,320	65	0.10	0.35	0.0
Peanut meal, solvent	92	47.4	39	—	1,700	85	0.20	0.65	—
Sorghum, milo, grain	89	11.0	8	—	1,680	84	—	—	—
Soybean meal, solvent	89	45.8	40	—	1,640	82	0.32	0.67	0.1
Wheat grain, soft. Pacific grain	89	13.0	11	1,719	1,595	79	—	—	—
Wheat bran	89	16.0	13	1,855	1,193	57	0.14	1.17	—
Dry roughages									
Alfalfa hay, pre-bloom	89	19.1	16	—	1,160	58	1.89	0.27	202.3
Alfalfa hay, early bloom	90	16.6	12	1,869	853	40	1.12	0.21	51.9
Alfalfa hay, mid-bloom	89	15.2	—	—	—	—	1.20	0.20	13.6
Alfalfa hay, late bloom	88	14.0	—	—	—	—	1.13	0.18	15.1
Alfalfa hay, dehydrated	92	16.7	—	—	—	—	1.09	0.29	33.4
Bluegrass hay	90	12.1	8	1,873	850	31	—	—	—
Clover, red hay	88	13.1	7	1,773	874	43	1.42	0.19	15.0
Lespedeza, annual hay	90	14.8	8	1,945	837	39	—	—	—
Oat hay, early bloom	93	4.3	5	1,860	500	26	0.23	0.21	40.4
Peanut hay, without nuts	92	5.3	6	1,878	830	46	—	—	—
Soybean hay	89	14.5	9	1,792	683	45	1.15	0.20	14.4
Sudan-grass hay	89	11.3	6	1,760	920	43	0.50	0.28	—
Vetch, common hay	88	17.6	10	1,796	945	46	1.20	0.30	183.0
Green roughages, roots and tubers									
Cabbage, aerial	8	1.7	1	154	155	8.0	—	—	—
Carrots, roots	12	1.2	1	218	198	10.8	0.05	0.04	—
Rutabaga, roots	13	1.3	1	236	230	10.0	—	—	—
Potatoes, sweet, tubers	42	1.8	1	785	709	28.0	—	—	—
Turnips, roots	9	1.2	1	145	140	7.4	0.06	0.02	—

[1] Values may be different in other publications because data are summarized to date for each publication. The composition of mixed roughages can be computed as weighted means from the figures given for the pure species making up the mixtures. A dash (—) indicates that no data are available.

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