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NUTRIENT REQUIREMENTS OF
DOMESTIC ANIMALS

Number 6

Nutrient Requirements of Horses

Second Revised Edition, 1966

A Report of the
SUBCOMMITTEE ON HORSE NUTRITION
COMMITTEE ON ANIMAL NUTRITION
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FOREWORD

This report on the *Nutrient Requirements of Horses* is a revision of the original report published March 1949. The revision was deemed desirable (1) to conform to the philosophy of the Committee on Animal Nutrition of estimating actual requirements rather than developing recommended allowances that include "margins of safety," (2) to incorporate the results of new information that may have accumulated in the past 10 years, and (3) to reinterpret the data in the original report, keeping in mind the decreasing use of the heavy horse as a source of power and the increasing popularity of light horses for recreational purposes.

Since there is a lack of specialized horse nutritionists in this country, it is not surprising that little new information has accumulated on nutrient requirements for horses during the last 10 years. Thus, the major revisions in this edition are the removal of "safety factors" inherent in recommended allowances and, in some instances, the reinterpretion of the older literature in the light of the advanced knowledge in the general field of animal nutrition.

INTRODUCTION

Specific information on the nutrient requirements of the horse is sparse indeed in comparison with that for other species. Thus, the data presented in this report, as in the original, are derived in many cases from experimental results obtained with cattle. We realize this is an unfortunate necessity, and it modifies the strength of our conclusions. Another reason for being modest about the accuracy of the calculated and estimated requirements lies in the nature of the horse. The variability of equine temperament necessarily causes great variation in energy requirement under practical conditions of maintenance. The average maintenance requirements may vary not only with nervous disposition but also with the condition of the environment. An amount of ration that is perfectly adequate for weight maintenance in the summer is likely to fall far short of this goal in a cold winter. At the moment we have no adequate data to express this relationship in practical terms. The data presented in this report are to be used only as guides. The proper feeding of individual horses remains, in the last analysis, an art that defies arithmetic.

The data in Table 1 show our best estimates of the daily nutrient needs of horses of different ages and varied mature weight. Table 2 presents the data on nutrient requirements expressed as percentages of the air-dry ration. It is in this form that the data are most useful for ration evaluation.

TABLE 1. DAILY NUTRIENT REQUIREMENTS OF HORSES
(Based on Air-Dry Feed Containing 90 Percent Dry Matter)

				Daily Nutrients per Animal							
Body Weight kg	Age months	Average Daily Gains kg	Daily Feed • Animal kg	Total Protein • kg	Digestible Protain kg	TDN kg	DE • Mcal	Ca gm	P gm	Carotene mg	Vitamin A IU (thousands)
GROWING HORSES 270-kg MATURE WEIGHT											
90	3.5	0.41	2.77	0.36	0.24	1.72	7.6	11	10	3	1.7
185	14.0	0.18	2.68	0.27	0.20	1.68	7.4	11	11	6	3.3
270	42.0	0	3.40	0.27	0.19	2.13	9.4	6	6	9	5.0
GROWING HORSES 365-kg MATURE WEIGHT											
90	2.6	0.64	3.04	0.50	0.34	1.91	8.4	14	11	3	1.7
185	8.0	0.41	4.26	0.41	0.28	2.68	11.8	17	13	6	3.3
270	19.0	0.23	4.72	0.36	0.27	2.95	13.0	13	13	9	5.0
365	44.0	0	4.22	0.32	0.23	2.63	11.6	9	9	12	6.7
GROWING HORSES 455-kg MATURE WEIGHT											
90	2.0	0.73	3.04	0.54	0.38	1.91	8.4	16	11	3	1.7
185	6.0	0.54	4.49	0.50	0.34	2.81	12.4	15	12	6	3.3
270	14.0	0.36	5.17	0.45	0.30	3.22	14.2	14	12	9	5.0
365	24.0	0.23	5.58	0.41	0.29	3.49	15.4	13	12	12	6.7
455	44.0	0	4.94	0.41	0.27	3.08	13.6	11	11	15	8.3
GROWING HORSES 545-kg MATURE WEIGHT											
90	1.9	1.00	3.40	0.82	0.50	2.13	9.4	19	16	3	1.7
185	5.2	0.82	5.08	0.64	0.45	3.18	14.0	18	17	6	3.3
270	10.0	0.59	5.94	0.54	0.39	3.72	16.4	18	17	9	5.0
365	17.0	0.36	6.08	0.50	0.34	3.81	16.8	18	17	12	6.7
455	25.0	0.18	6.08	0.45	0.32	3.81	16.8	12	12	15	8.3
545	45.0	0	5.67	0.45	0.31	3.54	15.6	12	12	18	10.0
GROWING HORSES 635-kg MATURE WEIGHT											
90	1.2	1.22	3.63	0.86	0.60	2.27	10.0	24	17	3	1.7
185	4.0	1.00	5.31	0.77	0.54	3.31	14.6	21	17	6	3.3
270	7.5	0.82	6.53	0.68	0.49	4.08	18.0	19	17	9	5.0
365	12.0	0.59	6.99	0.64	0.43	4.35	19.2	18	17	12	6.7
455	19.5	0.36	6.99	0.54	0.38	4.35	19.2	14	14	15	8.3
545	26.0	0.18	6.80	0.50	0.36	4.26	18.8	13	13	18	10.0
635	45.0	0	6.35	0.50	0.35	3.99	17.6	13	13	21	11.7

TABLE 1. Continued

Body Weight kg	Daily Feed kg	Total Protein kg	Daily Milk kg	Daily Nutrients per Animal: Digestible Protein kg	TDN kg	DE Mcal	Ca gm	P gm	Carotene mg	Vitamin A IU (thousands)
MATURE HORSES AT LIGHT WORK										
185	3.76	0.20	—	0.14	2.36	10.4	6	6	6	3.3
270	5.08	0.26	—	0.19	3.18	14.0	9	9	9	5.0
365	6.26	0.33	—	0.23	3.90	17.2	10	10	12	6.7
455	7.39	0.39	—	0.27	4.63	20.4	12	12	15	8.3
545	8.48	0.45	—	0.31	5.31	23.4	14	14	18	10.0
635	9.53	0.50	—	0.35	5.94	26.2	16	16	21	11.7
MATURE HORSES AT MEDIUM WORK										
185	4.35	0.20	—	0.14	2.72	12.0	8	8	6	3.3
270	5.90	0.26	—	0.19	3.67	16.2	10	10	9	5.0
365	7.35	0.33	—	0.23	4.58	20.2	12	12	12	6.7
455	8.62	0.39	—	0.27	5.40	23.8	14	14	15	8.3
545	9.93	0.45	—	0.31	6.21	27.4	16	16	18	10.0
635	11.11	0.50	—	0.35	6.94	30.6	18	18	21	11.7
MATURE HORSES, LAST QUARTER OF PREGNANCY										
185	2.63	0.26	—	0.18	1.63	7.2	9	8	28	9.3
270	3.63	0.36	—	0.25	2.27	10.0	12	11	42	14.0
365	4.45	0.44	—	0.30	2.77	12.2	14	13	56	18.7
455	5.31	0.51	—	0.36	3.31	14.6	16	15	70	23.3
545	6.08	0.59	—	0.42	3.81	16.8	18	17	84	28.0
635	6.80	0.67	—	0.47	4.26	18.8	20	19	98	32.7
MATURE HORSES, LACTATION PEAK										
185	6.99	0.79	14.5	0.55	4.35	19.2	18	13	28	9.3
270	7.98	0.89	16.3	0.63	4.99	22.0	23	18	42	14.0
365	9.43	1.06	19.0	0.74	5.90	26.0	27	22	56	18.7
455	10.43	1.16	20.0	0.81	6.53	28.8	30	24	70	23.3
545	11.52	1.30	22.0	0.91	7.21	31.8	34	27	84	28.0
635	13.15	1.41	23.6	0.98	8.21	36.2	37	30	98	32.7

[a] Based on 62.5 percent TDN in air-dry matter.
[b] Based on 70 percent apparent digestibility of protein.
[c] Based on 4.4 Mcal per kg TDN.

TABLE 2. NUTRIENT REQUIREMENTS OF HORSES
(Expressed as Percentage Composition of Air-Dry Rations)

Body Weight kg	Average Daily Gain kg	Daily Feed kg	Percentage, or Amount per kg, of Feed							
			Total Protein %	Digestible Protein %	TDN %	DE Mcal/kg	Ca %	P %	Carotene mg/kg	Vitamin A IU/kg
GROWING HORSES 270-kg MATURE WEIGHT										
90	0.41	2.77	13.1	8.7	63	2.75	0.40	0.36	0.9	550
185	0.18	2.68	10.1	7.3	63	2.75	0.41	0.41	1.5	840
270	0	3.40	8.0	5.3	63	2.75	0.18	0.18	2.6	1,480
GROWING HORSES 365-kg MATURE WEIGHT										
90	0.64	3.04	16.4	11.2	63	2.75	0.46	0.36	0.9	550
185	0.41	4.26	9.6	6.6	63	2.75	0.40	0.30	1.3	770
270	0.23	4.72	7.7	5.7	63	2.75	0.28	0.28	2.0	1,060
365	0	4.22	7.5	5.5	63	2.75	0.21	0.21	2.9	1,590
GROWING HORSES 455-kg MATURE WEIGHT										
90	0.73	3.04	17.9	12.5	63	2.75	0.52	0.36	0.9	550
185	0.54	4.49	11.1	7.6	63	2.75	0.33	0.27	1.3	730
270	0.36	5.17	8.8	5.9	63	2.75	0.27	0.23	1.8	970
365	0.23	5.58	7.3	5.3	63	2.75	0.23	0.22	2.2	1,190
455	0	4.94	8.2	5.5	63	2.75	0.22	0.22	3.1	1,680
GROWING HORSES 545-kg MATURE WEIGHT										
90	1.00	3.40	21.3	14.8	63	2.75	0.56	0.47	0.9	550
185	0.82	5.08	12.5	8.9	63	2.75	0.35	0.33	1.3	750
270	0.59	5.94	9.2	6.7	63	2.75	0.30	0.29	1.5	880
365	0.36	6.08	8.2	5.7	63	2.75	0.30	0.27	2.0	1,100
455	0.18	6.08	7.4	5.3	63	2.75	0.20	0.20	2.4	1,370
545	0	5.67	8.0	5.5	63	2.75	0.21	0.21	3.1	1,760
GROWING HORSES 635-kg MATURE WEIGHT										
90	1.22	3.63	23.8	16.5	63	2.75	0.66	0.47	0.9	550
185	1.00	5.31	14.5	10.0	63	2.75	0.40	0.32	1.1	640
270	0.82	6.53	10.4	7.4	63	2.75	0.29	0.26	1.5	820
365	0.59	6.99	9.0	6.2	63	2.75	0.26	0.24	1.8	950
455	0.36	6.99	7.8	5.5	63	2.75	0.20	0.20	2.2	1,190
545	0.18	6.80	7.3	5.3	63	2.75	0.20	0.20	2.6	1,480
635	0	6.35	7.8	5.5	63	2.75	0.20	0.20	3.3	1,850

TABLE 2. Continued

Body Weight kg	Daily Feed kg	Percentage, or Amount Per kg, of Feed							
		Total Protein %	Digestible Protein %	TDN %	DE Mcal/kg	Ca %	P %	Carotene mg/kg	Vitamin A IU/kg
MATURE HORSES AT LIGHT WORK									
185	3.76	5.2	3.6	63	2.75	0.16	0.16	1.5	880
270	5.08	5.2	3.7	63	2.75	0.16	0.16	1.8	990
365	6.26	5.3	3.7	63	2.75	0.16	0.16	2.0	1,080
455	7.39	5.3	3.7	63	2.75	0.16	0.16	2.0	1,130
545	8.48	5.3	3.7	63	2.75	0.16	0.16	2.2	1,170
635	9.53	5.2	3.7	63	2.75	0.16	0.16	2.2	1,240
MATURE HORSES AT MEDIUM WORK									
185	4.35	4.4	3.1	63	2.75	0.18	0.18	1.3	750
270	5.90	4.5	3.2	63	2.75	0.17	0.17	1.5	840
365	7.35	4.5	3.2	63	2.75	0.16	0.16	1.5	900
455	8.62	4.5	3.2	63	2.75	0.16	0.16	1.8	970
545	9.93	4.5	3.2	63	2.75	0.16	0.16	1.8	1,020
635	11.11	4.5	3.2	63	2.75	0.16	0.16	2.0	1,060
MARES, LAST QUARTER OF PREGNANCY									
185	2.63	9.8	6.9	63	2.75	0.34	0.30	10.6	3,530
270	3.63	9.9	6.9	63	2.75	0.33	0.30	11.7	3,860
365	4.45	9.8	6.8	63	2.75	0.31	0.29	12.6	4,210
455	5.31	9.7	6.8	63	2.75	0.30	0.28	13.2	4,390
545	6.08	9.8	6.9	63	2.75	0.30	0.28	13.9	4,610
635	6.80	9.8	6.9	63	2.75	0.29	0.28	14.3	4,180
MARES, PEAK OF LACTATION									
185	6.99	11.3	7.9	63	2.75	0.26	0.19	4.0	1,320
270	7.98	11.2	7.8	63	2.75	0.29	0.23	5.3	1,760
365	9.43	11.3	7.9	63	2.75	0.29	0.23	6.0	1,980
455	10.43	11.1	7.8	63	2.75	0.29	0.23	6.6	2,230
545	11.52	11.3	7.9	63	2.75	0.29	0.23	7.3	2,430
635	13.15	10.7	7.5	63	2.75	0.29	0.23	7.5	2,490

TOTAL DIGESTIBLE NUTRIENT AND DIGESTIBLE ENERGY REQUIREMENTS

MAINTENANCE

In accord with previous calculations, it is judged that the energy requirement for maintenance equals twice the basal metabolic rate. The maintenance value per 450 kg live weight amounts then to 13,600 kcal of digestible energy (DE), or 3.1 kg total digestible nutrients (TDN), and may be assumed to vary with the three-fourths power of body weight. Thus, values may be calculated for any given body weight by either of the following equations, assuming 4,410 kcal per kg of TDN:

$$\text{DE (kcal)} = 138.3\ W_{kg}^{0.75},$$

$$\text{TDN (kg)} = 0.031\ W_{kg}^{0.75}.$$

WORK

Energy requirements for horses at light and at medium work are assumed to be 3.0 and 3.5 times their basal metabolism. These data correspond to recommendations by Morrison (4) for similar work categories and to those by Brody (1) for horses working 2 to 3 hours and to 4 to 5 hours daily. Since intensity of "work" can vary so widely, it is obvious that these data provide only a rough guide to actual feeding practice.

PREGNANCY

From analytical data on the composition of the products of conception it is calculated that they contain 1,040 kcal of gross energy (GE) per kg. It is further estimated on the basis of the available literature that these products amount to 12 percent of the body weight of mares below 360 kg of body weight and 10 percent for mares weighing 360 kg or more. It is further assumed that the utilization of DE for growth of fetus and associated tissues is 60 percent. Since most of this tissue growth occurs during the last 25 percent of the gestation period, the added requirements are calculated entirely for this period. Thus, a 450-kg mare will deposit $454 \times 0.10 \times 1{,}040$ kcal ($=47{,}200$ kcal) in the last 85 days of pregnancy. This amounts to 555 kcal of GE daily or 60 percent of the DE allowance to be added above the maintenance requirement. Thus, the DE requirement is 925 kcal or 0.21 kg TDN daily. It is also recognized that a mare will be less active toward the end of pregnancy and because of this may have a lower maintenance requirement. It is also recognized that there may be a "heat increment of pregnancy." Since these factors act opposingly and we have no good estimate of

them, we have chosen not to include them in our calculations.

LACTATION

On the basis of its average composition, mare milk is calculated to contain 475 kcal GE per kg. It is assumed that the horse converts DE into milk energy with 60 percent efficiency, as has been estimated for the cow. Thus, 792 kcal of DE or 0.18 kg TDN are required per kg of milk produced. Data on milk production of mares are scant. *Maximum* likely rates may be calculated from growth requirement of growing horses and energy content of mare milk, assuming at 8 weeks of age all energy intake is by way of milk. Such a calculation shows that mares whose mature weight is 270, 360, 450, and 545 kg might produce at this stage of lactation 16, 19, 20, and 22 kg of milk daily. Daily DE required above maintenance for these rates of production amounts to 13.0, 15.2, 15.8, and 17.6 Mcal (1 Mcal $\approx$ 1,000 kcal). Average milk production by mares is likely to approximate 40 percent of the above figures.

GROWTH

In calculating energy requirements for growth the basic data of Garrett *et al.* (2) have been employed. Their data relative to beef cattle show, for example, that TDN required in the ration above maintenance for each kg of gain equals 0.17 $W^{3/4}$ kg. This relationship was derived from and is applicable to animals with a mature weight similar to that of beef cattle. It takes into account that the energy-content of a pound of gain increases and the efficiency of use of TDN for gain decreases with increasing physiologic age of the animal. The above relationship may be applied to animals of different mature weights if it is expressed in terms of percentage mature weight rather than body weight itself. This assumes that at a given physiologic age the efficiency and caloric content of gains are similar for animals of varying mature weight. The working equation thus becomes

$$\text{TDN above maintenance} = \text{kg gain } (0.84 + 1.14\,X - 2.2\,X^2),$$

in which X = fraction of adult weight.

PROTEIN REQUIREMENT

MAINTENANCE

Protein requirements for maintenance of horses up to 635 kg of body weight were computed using a base value of 0.27 kg of digestible crude protein (DCP) per 450 kg of body weight. From this it can be calculated that DCP equals 0.00278 $W_{kg}^{0.75}$. That base value compares favorably with the requirement of 53 to 68 gm of DCP per 100 kg of body weight reported by Nitsche (6) and levels suggested by others. Such a base value, furthermore, has been recommended by other subcommittees of the National Research Council Committee on Nutrition for the computation of protein requirements of other classes of livestock.

WORK

The protein requirement measured by nitrogen balance is not measurably increased above the maintenance level by muscular activity, provided that energy demand is met adequately. Nitsche reported that digestible true protein requirement actually declined with increasing units of work done. To provide for maximum digestion of the increased energy required during work, however, several authors have proposed that the ratio between nitrogen-containing and nitrogen-free components of the ration be adjusted to approximately 1:9–11 for working horses as compared with 1:10–12 for nonworking horses. Olsson and Ruudvere in a review of the nutrition of the horse (7) noted the probability that many standards for protein requirement of work are too high. In practice, the increased energy required for work will be met by natural feeds containing sufficient protein to cover any possible increase in protein requirements.

REPRODUCTION

Protein deficiency may have an undesirable effect on the fertility of the mare. It would appear, however, that the recommended daily maintenance level of 0.27 kg of DCP per 450 kg of body weight is adequate. Daily increases of from 10 to 20 gm of DCP per 100 kg of body weight have been advised for stallions subjected to moderate intensity of breeding.

The accepted practice of keeping mares on a maintenance ration during all but the last quarter of gestation appears reasonable because fetal growth-rate is extremely low and probably highly efficient during the first three quarters of pregnancy. In the last quarter of gestation, it would appear that daily protein requirement would increase.

It is assumed that the total products of conception contain 11.2 percent protein and that half of this protein is deposited during the

last quarter of gestation. Further, it is assumed that the maintenance nitrogen requirement of the products of conception equals 0.00278 kg of digestible protein times weight in kilograms to the three-fourths power, as in the case of the mare. Finally, it is assumed that the utilization of digested protein for fetal growth is 50 percent. Thus, a 450-kg mare would be assumed to develop 45 kg of products of conception, containing 5.04 kg of protein. Maintenance of these tissues = $0.00278 \times 22.5_{kg}^{0.75}$ or 0.028 kg of digestible protein daily. To provide for their growth would require 5.04 kg/85 = 0.059 kg per day over the last 85 days of gestation and the digestible protein requirement would equal 0.0059 + 0.028 = 0.087 kg.

LACTATION

It is estimated that the average concentration of protein in mare milk is 2.0 percent and, in common with recommendations concerning cattle, that allowance of 35 percent in excess of that appearing in the milk will provide adequate digestible protein for lactation. Thus, for each kilogram of milk produced, 0.027 kg of digestible protein is required.

GROWTH

Relying on body-composition data of the Group II Missouri steers as reported by Moulton *et al.* (5) and as calculated by Mitchell (3), and on the assumption that 50 percent of digestible protein fed above maintenance will appear in the gain, the protein requirement for gain, Y, may be calculated by use of the following equation, in which X represents fraction of mature weight:

$$Y \text{ (kg digestible protein/kg gain)} = 0.448 - 0.152\,X - 0.0812\,X^2.$$

MINERAL REQUIREMENTS

Few definitive experiments on mineral requirements have been made. Working horses can perform moderate-to-heavy work for extended periods on rations largely composed of grass hay and farm grains plus saltfree-choice. One may, therefore, suppose that the mineral needs of the mature horse are modest and that horses are less sensitive to trace-element deficiencies than are ruminants. Nevertheless, the need for small amounts of trace minerals in rations of horses may be inferred from the many references indicating the value of blackstrap molasses and similar "conditioners" for horses maintained for long periods on low-quality hay. The requirements for a number of the minerals for growth and lactation are not available from controlled experiments with horses.

SALT

Salt requirements increase with perspiration losses. Fifty to 60 gm of salt may be lost in the sweat and 35 gm in the urine of horses at moderate work. Fifty to 60 gm of supplemental salt which can be supplied by free-choice feeding or 85 gm salt-equivalent in the total ration will meet the needs of most horses. Under warm or hot climatic conditions, working horses should have an adequate daily supply of salt to prevent the effects of heat stress. Long-term deficiency in cool climates will be manifested by depraved appetites, rough-hair coat, and, in growing or lactating animals, by reduced growth and milk production. There is little danger of over-feeding unless a salt-starved animal is suddenly exposed to an unlimited supply of salt, or if liberal amounts of water are unavailable. In such cases the animals may develop digestive disturbances. Severely poisoned animals die of salt cramps.

CALCIUM AND PHOSPHORUS

The calcium and phosphorus requirements for maintenance of a mature horse weighing 450 kg are estimated to be 15 gm of each per day. Higher phosphorus requirements for working horses are given to compensate for possible losses associated with phosphorus turnover. The calcium–phosphorus (Ca/P) ratio is maintained at not less that 1:1. Requirements for pregnant and lactating animals are based on tissue storage or milk production assuming 50 percent availability. The requirements for growing animals assume 80 percent availability of dietary mineral. They are based on the composition and growth rate of a limited number of horses and may not be representative of all breeds. Since aged animals are more wasteful of calcium and phosphorus than are young adults, the requirement for horses over 10 years of age is probably 50 percent over the figures shown.

Although young colts develop rickets, un-

complicated phosphorus deficiencies in horses are not usually seen except in animals maintained exclusively on dry pastures or low-quality roughages. The classical ration of grass hay and farm grains is deficient in calcium and adequate in phosphorus. The common bone disturbances (variously called osteomalacia, osteoporosis, and osteodystrophia fibrosa) that develop in adult horses fed such rations are probably due to the narrow Ca/P ratio. Osteomalacia may develop when rations with a Ca/P ratio of 0.8:1 are fed for 6 to 12 months, and the disturbance will progress rapidly when the ratio is 0.6:1. The disease may be arrested by adding calcium to increase the ratio to 1.4:1. If the concentration of calcium in a ration is below 0.15 percent or if feedstuffs unusually rich in phosphorus are fed, some calcium supplement will be needed. The effects of feeding excesses of calcium to horses have not been reported, but probably no more than 30 gm of limestone per day should be fed for extended periods.

MAGNESIUM AND POTASSIUM

No estimates of the magnesium or potassium requirements have been made. Grass tetany, which affects some grazing cattle and sheep, results from a disturbance of magnesium and perhaps potassium metabolism. It has not usually been observed in horses under the same conditions. Any ration containing at least 50 percent of forage can be expected to meet the magnesium and potassium needs of horses.

SULFUR

Although many horsemen add it to rations for various purposes, inorganic sulfur is not known to be an essential dietary constituent for the horse. Except in rather unusual situations the sulfur intake of horses will be at least 0.15 percent—a level which is apparently adequate.

IODINE

The iodine requirements, based on the fact that sea salt containing 1 part iodine in 500,000 parts salt is a satisfactory supplement, is estimated to be 0.10 mg per day.

Symptoms of iodine deficiency are apparently unknown in adult horses; however, the rations of pregnant mares in the goiter belt should be fortified with supplemental iodine. Foals from unsupplemented mares in the goiter belt are stillborn or weak. It would appear that the iodized salt on the present market contains more iodine than is needed, but, since iodine may be rapidly lost under certain conditions, no toxic effects have been reported. In fact, pregnant mares have been reported to respond favorably to weekly doses of 1 gm of potassium iodide.

COBALT

Horses have successfully grazed pastures so low in cobalt that ruminants have died when exclusively confined to them. The requirement therefore is less than 0.05 parts per million (ppm). An anemia in horses that responded to vitamin B_{12} treatment indicates, however, that a cobalt deficiency in horse rations is possible. There is no evidence that the horse requires a dietary source of vitamin B_{12}.

COPPER

Eight ppm of copper are adequate for growing horses. Levels ranging from 5 to 8 ppm will meet the requirements of mature horses.

The presence of large amounts of molybdenum in forages does not appear to cause as severe disturbances in horses as it does in ruminants. The interrelationship of sulfate on copper utilization has not been studied. Except in Australia, uncomplicated copper deficiency in horses apparently has not been reported.

IRON

On the basis of the performances of similar horses fed timothy hay–oats–corn rations with and without supplemental ferric salts, the requirement for iron is estimated to be less than 40 ppm.

MANGANESE

The requirements for manganese are not known, but most roughage contains fairly liberal quantities. This probably explains the failure to observe manganese deficiency in horses.

ZINC

Requirements are not known, but most roughages contain relatively abundant concentrations of zinc. No deficiency has yet been reported.

FLUORINE

The effects of fluorine on dental development are now known. Toxic effects of excess fluorine are not well documented, but phosphorus sources should contain no more than 0.1 percent fluorine.

MOLYBDENUM

No requirement for this element has been demonstrated. Toxic effects were mentioned under copper.

SELENIUM

Selenium has not been shown to be an essential nutrient for horses. In areas where feeds may contain from 5 to 40 ppm of selenium, a characteristic condition referred to as "alkali disease" develops in horses. Symptoms include loss of hair from tail and mane and the occurrence of a ring on a hoof below the coronary band. In advanced cases the hoof may slough off. In terminal stages of the disease, blindness and paralysis may occur.

VITAMIN REQUIREMENTS

Information on both the qualitative and quantitative vitamin requirements of the horse is very meager. It is a common view that the problem of vitamin nutrition of the horse is less than that of some other domestic animals. This view, however, may come from the lack of experimental work on the vitamin requirements of the horse. The following information is based on all published literature available to the committee. Whenever possible, an estimate is made of the requirements, and a description of deficiency symptoms, when known, is given.

CAROTENE AND VITAMIN A

The quantitative requirements for carotene and vitamin A are based on a minimum level of 1.5 mg of carotene per 45-kg body weight. This amount allows for growth and freedom from deficiency symptoms, but not for liver storage. A level of 7.0 mg per 45 kg is set for pregnancy and lactation since it has been shown that three times the minimum level will allow cattle to calve normally, but will not prevent deficiency symptoms from appearing shortly in the calves. Five times the minimum level is sufficient for normal calving and prevention of symptoms in the suckling calf. The levels of vitamin A are calculated on the basis that, at the minimum level, it requires six times as much carotene as vitamin A and 10 times as much as the more liberal level for pregnancy and lactation. The units of vitamin A were calculated on the basis that 0.3 μgm of vitamin A (alcohol) equals one unit. Carotene can be converted to units by considering that 1 μgm of mixed carotene or 0.6 μgm of β-carotene is equal to one unit of vitamin A activity.

A deficiency of vitamin A is characterized by night blindness, lachrymation, keratinization of the cornea, respiratory symptoms, abscesses of the sublingual gland, incoordination, reproductive difficulties, capricious appetite, and progressive weakness. The hoofs of deficient animals may show a pathological syndrome similar to increased scaling or epidermis. That the leg bones may be affected is indicated by failure of mineralization of the Haversian systems of these bones. A vitamin A deficiency is apparently not the cause of the joint lesions sometimes encountered in horses.

The amount of carotene present in forage is usually indicated by the degree of green color. Forage allowed to reach the seed stage, or exposed to rains during the drying process, or stored for a long period is likely to have lost a high proportion of its vitamin A value. The intake of carotene by horses fed rations devoid of good-quality green hay or silage is likely to be below their requirements. No ill effects may be apparent for several months or a year provided the animals have a good store of vitamin A. Nevertheless, it is sound nutritional practice to provide horses with some feeds that will supply at least the minimum requirements, and higher amounts should be provided for mares in foal.

VITAMIN D

Experiments on the vitamin D requirements of horses are not clear-cut although it is commonly assumed that horses usually consume enough sun-cured hay together with the vitamin D obtained by the action of sunlight upon the skin to protect them from symptoms of vitamin D deficiency. If, however, they are confined with restricted exposure to sunlight the hay may not always supply sufficient vitamin D. Although requirements for the horse are not known, it may be estimated from requirements of other species that 300 IU of vitamin D per 45 kg of body weight should be sufficient.

Although there has been no experimental observation, a deficiency of vitamin D in the horse would probably cause the typical symptoms produced in other species.

VITAMIN E

No work has been undertaken in which uncomplicated vitamin E deficiency has been produced in horses. Investigations with cattle and sheep have not shown a beneficial effect of vitamin E in treating sterility, although they have shown this vitamin to be related to muscular dystrophy or white muscle disease. A few reports have claimed beneficial effects on reproduction in horses, but the results have not been clear-cut and uncomplicated. Dietary supplementation with this vitamin has not been shown unequivocally to be beneficial for either prevention of reproductive troubles or muscular dystrophy in the horse.

ASCORBIC ACID

The meager information on ascorbic acid (vitamin C) is conflicting and allows no definite conclusions. There is evidence that, when ascorbic acid is fed to horses, large amounts are destroyed in the digestive tract. Studies with mares and stallions indicate a correlation between breeding performance and blood ascorbic acid levels. Ascorbic acid feeding to barren mares, however, has been tried only in a limited manner and the results are inconclusive.

THIAMINE

A need for thiamine by the horse has been demonstrated, although the exact conditions under which a deficiency might be expected are not known. Thiamine is synthesized in the lower gut of the horse by bacterial action. The amount absorbed, however, may not always meet the full requirements. Thiamine deficiency has been produced experimentally and has been observed in horses fed on poor-quality hay and grain. The quantitative thiamine requirement is unknown but an intake of approximately 0.14 mg per 45 kg of body weight has proved inadequate; 2.5 mg per 45 kg, however, will maintain peak food consumption, normal gains, and normal levels of thiamine in skeletal muscle.

Symptoms of a thiamine deficiency are decreased feed consumption, loss of weight, incoordination (especially in the hind quarters), lowered blood thiamine, and elevated blood pyruvic acid. Postmortem examination will reveal a dilated and hypertrophied heart.

Bracken (*Pteris aquilina*) poisoning in horses produces symptoms similar to those of thiamine deficiency, and animals will respond to thiamine administered subcutaneously at the rate of 50 to 100 mg, repeated as necessary. Another condition in horses known as "mare's tail" poisoning, caused by the consumption of equisetum, also responds to thiamine therapy. Apparently these two plants induce a thiamine deficiency by a mechanism now unknown.

RIBOFLAVIN

Although not entirely above criticism, the evidence appears to be sufficient that the horse may require riboflavin in the diet under certain unknown conditions. There have been

a number of reports implicating riboflavin in periodic ophthalmia in horses, sometimes known as "moon-blindness." Reports also indicate that periodic ophthalmia is one of the sequelae of leptospirosis in horses.

The first symptom of acute riboflavin deficiency is the appearance of catarrhal conjuctivitis in one or both eyes. This is accompanied by photophobia and lachrymation. Repeated attacks affect the retina, lens, and ocular fluids and often cause impaired vision or blindness. Deficiency symptoms have been prevented by feeding approximately 40 mg per head per day. One report indicates the riboflavin requirements may be met by 2.0 mg per 45 kg of body weight.

NIACIN

Some evidence indicates that niacin is synthesized by the horse. It was found that horses made normal gains on rations that provided approximately 0.10 mg of niacin per kg of body weight per day. When the daily intake was reduced to 0.01 mg per kg, the amount excreted in the urine and feces each exceeded the intake. Since the animals were gaining weight, this could be accounted for only on the basis of synthesis. It is of interest from a comparative biochemical standpoint that the chief end-product of niacin metabolism in the horse is not *N'*-methylnicotinamide as in the dog, man, or rat. The horse can convert dietary tryptophan to niacin. It would, therefore, be expected that the need of the horse for a dietary source of niacin may be influenced by the amount of tryptophan in the diet.

PANTOTHENIC ACID

Urinary-excretion studies with horses definitely show that the amount of pantothenic acid excreted by the renal pathway varies with the amount ingested. Shetland ponies on a daily intake of approximately 40 μgm per kg of body weight appeared to be as healthy as animals receiving higher levels. Whether or not pantothenic acid is a dietary essential for the horse is not certain at present, but it does appear that on rations made up of natural feeds, normally consumed by horses, there is little danger of a deficiency of the vitamin.

VITAMIN B_{12}

It has been reported that horses in poor nutritional condition showing anemia respond to administration of vitamin B_{12}. These reports need to be further substantiated before it can be stated with certainty that vitamin B_{12} is a dietary essential for horses.

OTHER VITAMINS

Information on the other vitamins is either lacking or is not sufficiently documented to report. It is hoped that this summary of existing information will stimulate further research in this interesting field. In addition to its importance to the horse feeder, the contribution to the field of comparative nutrition would be of great value.

FEED FOR HORSES

A compilation of the nutrient content and digestible nutrients of most common feeds has been made by the joint effort of the United States and Canadian National Research Councils and published as National Academy of Science—National Research Council Publication 1232. Most of the digestibility data published in this bulletin were obtained with cattle and sheep and thus are higher than would be obtained with horses. The major difference in digestive capability between ruminants and horses is of course in crude-fiber digestibility. Except for this difference it is likely that the digestion coefficients obtained with ruminants may be used for horse-ration evaluation. Since the available data are based on much more extensive research for the ruminants no separate tabulation has been made for horse feeds. The limited data that are available from experiments with horses may be found in the publications by Schneider (8) and by Olsson and Ruudvere (7).

The nutrients required by horses may be supplied economically from pasture, roughage, and concentrates. Free access to pasture and feeding the hay and concentrate in controlled quantities may supply a ration adequate to meet the needs of the horse. These nutrient demands vary with the stage of growth (expressed as percent of mature weight attained), gestation, lactation, age, and the amount of work performed.

Good grass–legume pastures plus iodized salt supply adequate nutrients to maintain adult horses performing light work and mares during pregnancy. Growing colts, lactating mares, and medium working horses, in addition to horses on poor pasture or hay, need supplements to satisfy their requirements.

Iodized salt in loose or granulated form should be fed free-choice. The salt should be in a protected feeder since exposure to sunlight and rain may permit the iodine to be lost readily.

PASTURE

Grass–legume pastures grown on well-fertilized soil under favorable climatic conditions are most desirable in feeding horses.

The season's first lush early pasture grasses may contain up to 40 percent protein on a dry basis but because of the high water content may contain inadequate carbohydrate energy to maintain active horses. During this period additional supplementation is needed. As pasture matures the dry matter and energy-content increases, the level of protein decreases. Heavy mature grasses remaining at the end of the pasture season may be utilized during the late fall and early winter with a supplement providing protein and vitamins A and D.

ROUGHAGE

High-quality legume hay, preferably alfalfa, or mixtures of grasses and legumes are desirable for feeding horses. Legume hays cut in the early bloom stage usually yield well and produce a high-quality palatable hay when dried quickly and harvested without losing leaves. The most digestible nutrients are in the leaves and the ratio of stems to leaves is important. Overly mature hay usually contains an excess of coarse stems.

Although oat straw and wheat straw are less desirable for horses than good hay, straw properly supplemented can be used as the only roughage.

CONCENTRATES

Oats are the most desirable single grains for horses since they are less concentrated than other grains and tend to prevent impaction. In areas where corn, barley, wheat, and milo may be less expensive they may be used but, if finely ground, may require care in feeding to avoid digestive upsets.

The suggested rations for practical horse production in Table 3 and 4 are based on ingredients generally available. Local grains and hays may replace those shown in the examples. In some areas, prairie hay may replace the timothy and even the alfalfa if additional calcium, vitamins, and energy can be provided. In other places, alfalfa may be the only roughage available.

TABLE 3. EXAMPLE RATIONS FOR GROWING HORSES (635-kg Mature Weight)

Weight kg	kg Feed Daily			
	Concentrates			
	Protein[a]	Grain[b]	Alfalfa	Timothy
90	0.9	2.27	0.45	—
185	0.9	2.27	1.14	1.14
270	—	3.18	1.80	1.80
365	—	2.27	2.95	2.95
455	—	1.80	3.60	3.60
545	—	1.80	4.50	4.50
635	—	1.80	4.75	4.75

[a] Protein (and mineral) concentrate equals dehulled soybean meal 90%, dicalcium phosphate 5%, and mineralized salt 5%.
[b] Grain concentrate equals corn 25%, oats 50%, and wheat bran 25%.

TABLE 4. EXAMPLE RATIONS FOR MATURE HORSES

	kg Daily		
	Concentrate[a]	Alfalfa	Timothy
MAINTENANCE			
275 kg	0.45	1.35	3.60
635 kg	0.68	2.75	5.90
LIGHT WORK			
275 kg	1.60	0.90	3.18
635 kg	2.75	1.80	6.35
MEDIUM WORK			
275 kg	2.25	1.35	3.18
635 kg	4.00	2.25	6.35
PREGNANT MARES			
275 kg	0.45	1.80	3.60
635 kg	0.68	3.60	5.90
LACTATING MARES			
275 kg	2.25	1.35	3.18
635 kg	4.00	2.25	6.35

[a] Corn 25%, oats 50%, and wheat bran 25%.

REQUIRED AND SUPPLIED NUTRIENTS

The data in Table 5 compare the nutrients supplied by the suggested rations for mature 275-kg and 635-kg horses and for growing horses of 635-kg mature weight with the nutrient requirements as calculated in this bulletin. Although these rations exceed the requirements for energy, digestible protein, carotene, calcium, and phosphorus, they help ensure desirable performance and also supply the requirements of those animals that may deviate from the normal.

INDIVIDUAL VARIATIONS

Individual variations in horses must also be considered since some "easy keepers" may require significantly less feed to maintain

TABLE 5. COMPARISON OF NUTRIENTS IN PRACTICAL RATIONS WITH DAILY NUTRIENT REQUIREMENTS OF HORSES

	TDN*, kg		Digestible Protein, kg		Calcium, gm		Phosphorus, gm		Carotene, mg	
	Required	Supplied	Required	Supplied	Required	Supplied	Required	Supplied	Required	Supplied
MATURE 270-kg HORSES										
Maintenance	2.0	3.2	0.18	0.40	6	42	6	15	9	120
Light Work	3.1	3.1	0.18	0.35	9	22	9	17	9	90
Medium Work	3.6	3.8	0.18	0.45	10	29	10	22	9	120
Pregnant Mare	2.3	3.1	0.25	0.35	12	35	11	14	42	150
Lactating Mare	4.9	5.0	0.63	0.70	23	49	18	30	42	120
MATURE 635-kg HORSES										
Maintenance	3.8	5.2	0.35	0.53	13	54	13	22	21	230
Light Work	5.1	6.0	0.35	0.64	16	43	16	32	21	180
Medium Work	6.9	7.0	0.35	0.82	18	51	18	40	21	210
Pregnant Mare	4.1	5.1	0.45	0.62	20	67	19	24	98	280
Lactating Mare	8.7	9.0	0.98	1.18	37	84	30	52	98	210
GROWING HORSES										
Weight kg / % Body Weight Daily										
90 4.0	2.3	2.5	0.59	0.64	24	24	17	27	3	30
185 3.0	3.2	3.4	0.54	0.77	21	36	17	31	6	80
270 2.5	4.0	4.0	0.50	0.54	19	34	17	32	9	130
365 2.25	4.4	4.5	0.44	0.64	18	52	17	26	12	210
455 2.0	4.4	4.9	0.37	0.68	14	63	14	38	15	260
545 2.0	4.2	5.8	0.36	0.77	13	79	13	30	18	320
635 1.8	3.6	6.0	0.35	0.82	13	82	13	31	21	360

* May be expressed as Mcal of DE by multiplying TDN by 4.4.

them in thrifty condition while others of the same breed and weight may require considerably more. Differences may be influenced by the temperament, previous nutrition, breed, size, age, management, and weather. These requirements meet the nutritional demands of "normal" horses, but feeding that takes individual variation into account still depends on the feeder's careful observation and good judgment.

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