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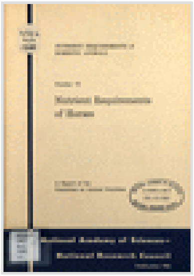

# Nutrient Requirements of Horses (1961)

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NUTRIENT REQUIREMENTS of DOMESTIC ANIMALS

Number VI

# Nutrient Requirements of Horses

*A Report of the*

N.R.C. COMMITTEE ON ANIMAL NUTRITION

*Prepared by the*

SUBCOMMITTEE ON HORSE NUTRITION

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## FOREWORD

This report on *Nutrient Requirements of Horses* is the sixth of a series of reports of this character by the Committee on Animal Nutrition of the National Research Council and its subcommittees. The preceding reports have dealt with poultry, swine, dairy cattle, beef cattle and sheep. The reports have been prepared for the use of animal nutritionists, livestock feeders and the feed manufacturing industry.

The *Nutrient Requirements of Horses* were developed by the Subcommittee on Horse Nutrition and have been approved by the Committee on Animal Nutrition. The allowances represent the first attempt in the history of animal nutrition to develop nutrient standards for horses by a group of animal nutritionists who have made a specialty of horse nutrition. Through such group action it is believed that standards of the highest possible degree of reliability, considering the available knowledge, have been developed.

The work of the Subcommittee on Horse Nutrition and of the Committee on Animal Nutrition on the *Nutrient Requirements of Horses* is not final. Whenever new experimental evidence is obtained on the nutritional requirements of horses, these nutrient allowances will be revised and enlarged so as to bring them up to date.

The members of the Committee on Animal Nutrition and of the Subcommitte on Horse Nutrition are given below:

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## NUTRIENT REQUIREMENTS OF HORSES

The importance of the horse as a source of farm power has declined during the past three decades as a consequence of economic conditions which have favored the mechanization of the farm. It is improbable, however, that complete mechanization can be obtained. In view of this, some horses will continue to be used as a source of farm power. Light horses are also used in the sport of racing and probably will be indefinitely because of public interest. The horse has furthermore come to occupy, in recent years, an increasingly important position in the field of recreation.

The Committee on Animal Nutrition of the National Research Council has considered it desirable, therefore, to develop *Nutrient Requirements of Horses* as has been done for the other types of domestic animals. These are presented in this report together with information on the effect of nutritional deficiencies in horses. Information on the composition of feeds commonly used for feeding horses is also included in the report. Information on the quantitative requirements of the horse for various nutrients is very limited, and there is very little known regarding breed differences or differences due to the various kinds of work performed. It may be expected that the nutritional requirements of the horse kept mainly for the performance of work differ somewhat from those of animals producing meat, milk, wool or eggs. The recommended allowances are considered adequate under practical conditions. Although specific knowledge of the nutritional requirements of mules is very limited, the Committee feels that the recommended nutrient allowances for horses may be used as a guide for the nutrient allowances for mules. The Committee hopes that the report may draw attention to the gaps in our knowledge of the nutritional requirements of horses and thereby stimulate investigations in this field.

Data on maintenance requirements of horses are so limited that the energy requirements of cows have been used to a large extent in calculating the feed requirements of horses. Likewise data on digestible nutrients of various feeds for horses are based largely on data obtained in digestion trials with ruminants. The recommendations given in Tables 1, 2 and 3, based on limited data and on computations, are necessarily tentative in nature, and serve better than any other purpose to emphasize the present need for careful experimental work on the nutrition of horses.

*Muscular Work.*—Only part of the energy expended during muscular contraction appears as useful work. To begin with, the theoretical maximum efficiency of a contracting muscle is only about 40 per cent (Hill, 1927). Additional energy is lost in the interaction of various sets of muscles, and a considerable loss is accounted for externally in the slipping of hoofs on the ground. As a result of these energy losses, the ratio of useful work accomplished by the horse to energy expended during work is not more than 25 per cent. Nevertheless, the efficiency level obtainable with horses is equal to the drawbar efficiency of most tractors now in use.

The gross efficiency (useful work expressed as percentage of energy consumed) of the horse can be calculated as follows: The energy allowance (Table 1) for an 1800 pound animal producing 8 horsepower hours (or $8 \times 1{,}980{,}000$ foot pounds) of useful work in 1 day is 22.5 pounds T.D.N. Since 1 pound T.D.N. equals 1814 Calories, and 641.3 Calories is equal to 1 horsepower hour (Brody, 1945), gross efficiency equals $\frac{8 \times 641.3}{22.5 \times 1814} \times 100$ or 12.6 per cent. Because both the nutrient allowances and work levels in Table 1 vary with the same power of body weight, the efficiency levels of horses of all sizes calculated from these data are equal. Most horses are worked less than 8 hours a day, and since gross efficiency declines as the work day is shortened, it follows that most horses work at gross efficiency levels below 12.6 per cent.

While only large horses ordinarily work at a rate as high as 1 horsepower during the entire day, the animals are capable of producing much more than this for short periods of time. At maximum load, for short periods, horses are able to accomplish from 7 to 13 horsepower of useful work. An animal's total energy expenditure during such periods of maximum exertion is 100 times the basal metabolic rate according to Brody (1945); this is about 12 times the energy expended by the same animals during ordinary hard work.

## Energy Requirements

The energy cost of maintenance may be considered to be about twice the basal metabolic rate according to Brody (1945) or 6.75 pounds T.D N. for a 1000 pound animal. Careful experimental work has demonstrated that such an allowance is adequate according to Morrison (1948) who reports that idle horses have been maintained for relatively long periods on 6.4 to 7.0 pounds T.D.N. daily per 1000 pounds live weight. However, Morrison recommends that a 1000 pound idle horse be allowed 7 to 9 pounds T.D.N. daily.

The Table 1 maintenance allowance is twice basal metabolism plus an additional allowance equal to one-third the basal metabolic rate to meet requirements for normal activity and to serve as a safety factor, or 7.9 pounds T.D.N. for a 1000 pound horse.

Allowances given in Tables 1 and 2 for animals of various sizes are based on the assumption that the energy requirements for maintenance, work, growth, and milk production vary with the three-fourths power of body weight. The relationships between body weight and physiological functions of animals have been discussed by Brody (1945) and Kleiber (1947).

*Energy Requirements for Work.*—The energy allowances given in Table 1 for horses at light work are 3 times the basal metabolic rate and correspond to Brody's allowances for horses working 2 to 3 hours daily and to Morrison's standard for horses at light work. Horses at medium work are allowed 3.5 times the energy of their basal metabolism, which corresponds to Brody's allowances for horses working 4 to 5 hours a day, and to the Morrison standard for horses at medium work. Since the actual work done by farm horses does not average more than 5 hours daily, the allowances for horses at medium work should be sufficient for most farm horses under ordinary work conditions. The allowances for horses at hard work provide sufficient energy for horses working 8 hours a day. This allowance is equal to 4.3 times the basal metabolic rate.

Only the time actually spent at work should be counted as work-time. The time spent standing in harness is not part of the true work period, since horses expend no more energy while standing than while lying down (Winchester, 1943; Brody et al., 1943).

*Energy Requirements of Pregnant Mares.*—The maintenance ration is generally considered adequate for the mare during the first three quarters of the period of pregnancy as fetal growth is relatively slow at this time.* The energy requirements during the last quarter of the pregnancy period have been estimated on the basis of available information and calculations.

The following example illustrates the method used in calculating the net amounts of nutrients incorporated in the fetus, placenta, and amniotic fluid during the last quarter of pregnancy.

*Produced by Draft Mare (1800 pounds body weight)*

| | Weight | Protein | | Fat | | | T.D.N. Energy |
|---|---|---|---|---|---|---|---|
| | *lb.* | % | *lb.* | % | *lb.* | *lb.* × 2.25 | *lb.* |
| Foal at birth | 120 | 14.2 | 17.0 | 2.5 | 3.0 | 6.8 | 23.8 |
| Amniotic fluid | 49 | 3.4 | 1.7 | 0.9 | 0.45 | 1.0 | 2.7 |
| Placenta | 24 | 12.2 | 2.9 | 0.9 | 0.2 | 0.5 | 3.4 |
| Total | | | | | | | 29.9 |

The mean daily gain in T.D.N. can be obtained by dividing the result of the calculation, above, by the number of days in the last quarter of pregnancy. Thus, $\frac{29.9}{85} = 0.35$ pound T.D.N. (mean net daily gain). If the availability of nutrients for growth of the fetus is assumed to be 60 per cent, then 0.35 ÷ 0.6 per cent or 0.6 pound T.D.N. should be allowed daily.

In addition to the allowance for fetal growth, and for maintenance of the mare during pregnancy, allowance for an increased metabolic rate of the mare must be made. This increase (which includes heat production of the fetus) is of the order of 30 per cent during the last quarter of pregnancy in cows, and limited data indicate that this is also true in mares (Brody, 1945). Including the allowance for increased metabolism, the daily energy requirement of a mare during the last quarter of pregnancy is that given in the following example:

*Daily Allowance for Pregnant Draft Mare (1800 pounds)*

| | T.D.N. Daily *lb.* |
|---|---|
| Normal maintenance | 12.0 |
| For fetus, placenta and amniotic fluid | 0.6 |
| Heat increment of pregnancy (30% maintenance) | 3.6 |
| Total | 16.2 |

* Eckles (1916) reported that cows, kept on maintenance rations throughout pregnancy, made normal pregnancy gains in body weight.

*Energy Requirements of Lactating Mares.*—On the basis of information reported by Morrison (1948), it may be assumed that the mean daily milk production of 1600 pound mares is 50 pounds, that the T.D.N. content of mares' milk is 10.1 per cent, and that the T.D.N. secreted daily as milk is therefore about 5 pounds. Then the daily allowance of digestible nutrients for milk production should be 8.33 pounds, assuming the availability of feed nutrients for milk production to be 60 per cent.

TABLE 1

DAILY ALLOWANCES FOR MATURE HORSES

| Body Weight | Digestible Protein | | | | Total Digestible Nutrients | | | | Dry Matter—90% basis | | | | Calcium* | Phosphorus* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maintenance | Work | | | Maintenance | Work | | | Maintenance | Work | | | | |
| | | Light | Medium | Hard | | Light | Medium | Hard | | Light | Medium | Hard | | |
| *lb.* | *lb.* | *lb.* | *lb.* | *lb.* | *lb.* | *lb.* | *lb.* | *lb.* | *lb.* | *lb.* | *lb.* | *lb.* | *gm.* | *gm.* |
| 400 | 0.31 | 0.38 | 0.46 | 0.52 | 3.9 | 5.1 | 5.9 | 7.3 | 6.2 | 8.2 | 9.4 | 11.0 | 7.3 | 8.5 |
| 600 | 0.42 | 0.52 | 0.62 | 0.70 | 5.3 | 6.9 | 8.0 | 9.9 | 8.5 | 11.0 | 12.8 | 14.8 | 9.9 | 11.0 |
| 800 | 0.53 | 0.65 | 0.77 | 0.87 | 6.6 | 8.6 | 10.0 | 12.3 | 10.6 | 13.8 | 15.9 | 18.4 | 12.2 | 13.7 |
| 1000 | 0.62 | 0.76 | 0.91 | 1.03 | 7.9 | 10.1 | 11.8 | 14.6 | 12.6 | 16.2 | 18.9 | 21.9 | 13.7 | 15.4 |
| 1200 | 0.71 | 0.88 | 1.04 | 1.18 | 9.0 | 11.6 | 13.5 | 16.7 | 14.4 | 18.6 | 21.6 | 25.1 | 15.7 | 17.7 |
| 1400 | 0.80 | 0.98 | 1.17 | 1.33 | 10.1 | 13.0 | 15.1 | 18.8 | 16.2 | 20.8 | 24.2 | 28.2 | 17.6 | 19.8 |
| 1600 | 0.88 | 1.09 | 1.29 | 1.47 | 11.1 | 14.4 | 16.7 | 20.7 | 17.8 | 23.0 | 26.7 | 31.0 | 19.4 | 21.8 |
| 1800 | 0.97 | 1.19 | 1.40 | 1.60 | 12.2 | 15.8 | 18.2 | 22.7 | 19.5 | 25.3 | 29.1 | 34.0 | 21.1 | 23.8 |
| **Mares—Last Quarter of Pregnancy** | | | | | | | | | | | | | | |
| 400 | | 0.46 | | | | 5.4 | | | | 8.6 | | | 7.8 | 7.8 |
| 600 | | 0.62 | | | | 7.3 | | | | 11.7 | | | 10.6 | 10.6 |
| 800 | | 0.77 | | | | 9.0 | | | | 14.4 | | | 13.1 | 13.1 |
| 1000 | | 0.91 | | | | 10.6 | | | | 17.0 | | | 15.4 | 15.4 |
| 1200 | | 1.04 | | | | 12.2 | | | | 19.5 | | | 17.7 | 17.7 |
| 1400 | | 1.17 | | | | 13.7 | | | | 21.9 | | | 19.9 | 19.9 |
| 1600 | | 1.29 | | | | 15.2 | | | | 24.3 | | | 22.1 | 22.1 |
| 1800 | | 1.41 | | | | 16.2 | | | | 26.6 | | | 24.2 | 24.2 |
| **Mares—Lactating** | | | | | | | | | | | | | | |
| 400 | | 1.01 | | | | 8.8 | | | | 12.3 | | | 12.3 | 11.2 |
| 600 | | 1.37 | | | | 11.9 | | | | 16.7 | | | 16.7 | 15.2 |
| 800 | | 1.70 | | | | 14.7 | | | | 20.6 | | | 20.6 | 18.7 |
| 1000 | | 2.01 | | | | 17.4 | | | | 24.4 | | | 24.4 | 22.2 |
| 1200 | | 2.30 | | | | 20.0 | | | | 28.0 | | | 28.0 | 25.4 |
| 1400 | | 2.59 | | | | 22.4 | | | | 31.4 | | | 31.4 | 28.5 |
| 1600 | | 2.87 | | | | 24.9 | | | | 34.9 | | | 34.9 | 31.7 |
| 1800 | | 3.12 | | | | 27.1 | | | | 37.9 | | | 37.9 | 34.4 |

* Calculated for horses at medium work.

An allowance of 50 per cent of maintenance is included in the figures for the energy requirements of lactating mares to take care of the heat increment of lactation. While statements appear in the literature to the effect that lactation does not increase heat production, such statements are based on measurements of metabolism during fasting, according to Brody (1945), who further states that "Under ordinary conditions, of course, lactating animals do not fast; indeed, they consume two or three times as much food as non-lactating animals"—"their heat production is perhaps twice as great as that of non-lactating animals, the exact value depending on the lactation level, and therefore food intake." At the lactation level which served as a basis for the calculation of requirements of lactating mares, given in Table 1, the heat increment of lactation is assumed to be 50 per cent of maintenance.

The daily energy requirements of a lactating mare may be calculated as follows:

*Lactating Draft Mare (1600 pounds)*

| | T.D.N. Daily lb. |
|---|---|
| Normal maintenance | 11.1 |
| T.D.N. in milk | 8.3 |
| Heat increment of lactation | 5.5 |
| Total | 24.9 |

This allowance is about the same as the standard allowances for cows when comparison is made on the basis of body size and of energy secreted as milk.

*Energy Requirements of Weaned Foals.*—Since experimental data on the nutrient requirements of growing horses are meager, estimates of the energy requirements of foals must be based largely upon calculations. The available data on growth and metabolic rates, activity and chemical changes in the body composition of growing animals have been used in estimating energy requirements.* Growth rates have been obtained from various sources as follows: Mitchell (1947a), 1800 pound Percherons; Brody (1945), Percherons of 1400 pound size, and some information on growth rates of horses of around 800 pounds body weight; Morrison (1948), horses of about 1100 pound size; and Earle (1948) ponies of around 400 pounds body size when fully grown.

In the calculation of energy requirements of growing horses, the following assumptions are made: (1) Protein in the ration has a biological value of 50 per cent; (2) Net availability of digestible nutrients is 60 per cent for growth and 70 per cent for maintenance; (3) One pound T.D.N. equals 1814 calories of energy (Brody, 1945); (4) The newly born foal contains the same percentages of protein and fat as does the calf, namely 14.2 and 2.5 per cent respectively (Brody, 1945); (5) The relationship between chemical composition and age of the growing horse is similar to that of the calf (Moulton, 1923); (6) The energy cost of activity is one-fifth that of maintenance in the young colt and declines with age.

The example given below shows the method of calculation used in estimating the energy requirements of a 400 pound draft colt 2.4 months of age and gaining 3.8 pounds daily.

The requirements of working colts can be estimated by adding the allowance above maintenance for a mature working animal to the ordinary allowance given the growing horse. For example, a fully grown horse weighing 1400 pounds is allowed 15.1 pounds T.D.N. while at medium work and

* It is assumed that chemical changes in the body of the growing horse are similar to those of the calf as reported by Moulton (1923).

10.1 pounds T.D.N. when idle, or a difference of 5 pounds T.D.N. for work. Then a growing 1400 pound horse at medium work should be allowed 5 pounds T.D.N. in addition to the regular allowance of 12.9 pounds T.D.N., or a total of 17.9 pounds T.D.N. per day.

### Protein Requirements

*Maintenance and Work.*—The protein allowances for maintenance given in Tables 1 and 2 are about four times the protein equivalent of endogenous nitrogen excretion. Brody (1945) has suggested that such allowances probably are sufficient for all warm-blooded animals. These allowances compare

*Daily Requirements*

| | | | | T.D.N. *lb.* |
|---|---|---|---|---|
| *For Maintenance:* | | | | |
| 400 (body weight in pounds) | × | 33.9 (maintenance requirement in Calories) | = 6168 Calories (24-hour, net maintenance) | |
| 6168 | ÷ | 1814 (Calories per lb. T.D.N.) | = 3.4 pounds T.D.N. | |
| 3.4 | ÷ | 0.7 (net availability for maintenance) | = | 4.9 |
| *For Activity* (one-fifth maintenance) | | | = | 1.0 |
| *For Protein:* | | | | |
| 3.8 (daily gain in pounds) | × | 0.149 (protein in 1 lb. of body Tissue) | = 0.57 pound protein net requirement | |
| 0.57 | ÷ | 0.5 (biological value of protein) | = | 1.14 |
| *For Fat:* | | | | |
| 3.8 (daily gain in pounds) | × | 0.045 (fat in 1 lb. of body tissue) | = 0.18 pound fat, net gain | |
| 0.18 | × | 2.25 (pounds T.D.N. per pound fat) | = 0.40 pound T.D.N., net gain | |
| 0.40 | ÷ | 0.6 (net availability for growth) | = | 0.67 |
| Total daily energy requirements | | | | 7.71 |

favorably with the 53 to 68 grams of crude protein per 100 kilograms of body weight that Nitsche (1939) found adequate for resting horses. This allowance, expressed in pounds, is 0.53 to 0.68 pound of protein per 1000 pounds of body weight. The maintenance allowance for a 1000 pound animal, given in Table 1, is 0.62 pound digestible protein.

Results obtained by Harvey et al. (1939) indicate that the allowances given in Table 1 for maintenance are also adequate for working horses. These experiments demonstrated that a daily ration in which the protein was entirely supplied by 3 pounds of oats and 20 pounds of timothy hay, equivalent to 0.86 pound of digestible protein according to Morrison (1948), was sufficient to keep 1680 pound Percherons in positive nitrogen balance not only during rest but while working at rates as high as 1.27 horsepower for over four hours daily. Other recent research has demonstrated that protein requirements are not measurably increased above the maintenance level by muscular activity, provided that the energy requirements are adequately met (Forbes, 1945).

TABLE 2

DAILY PROTEIN AND ENERGY ALLOWANCES FOR GROWING HORSES

Mature Weight in Pounds

| | 600 | | | | | 800 | | | | | 1000 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Age | Daily Gain | Dry Matter | Digestible Protein | T.D.N. | Age | Daily Gain | Dry Matter | Digestible Protein | T.D.N. | Age | Daily Gain | Dry Matter | Digestible Protein | T.D.N. |
| | *mo.* | *lb.* | *lb.* | *lb.* | *lb.* | *mo.* | *lb.* | *lb.* | *lb.* | *lb.* | *mo.* | *lb.* | *lb.* | *lb.* | *lb.* |
| 200 | 3.5 | 1.1 | 6.7 | 0.77 | 4.2 | 2.6 | 1.4 | 7.2 | 0.93 | 4.5 | 2.0 | 1.6 | 7.5 | 1.04 | 4.7 |
| 400 | 14.0 | 0.6 | 9.1 | 0.57 | 5.7 | 8.0 | 0.9 | 9.9 | 0.80 | 6.2 | 6.0 | 1.2 | 10.2 | 0.94 | 6.4 |
| 600 | 42.0 | 0.0 | 10.2 | 0.45 | 6.4 | 19.0 | 0.5 | 11.7 | 0.65 | 7.3 | 14.0 | 0.8 | 12.3 | 0.77 | 7.7 |
| 800 | | | | | | 44.0 | 0.0 | 12.6 | 0.54 | 7.9 | 24.0 | 0.5 | 13.8 | 0.74 | 8.6 |
| 1000 | | | | | | | | | | | 44.0 | 0.0 | 15.0 | 0.64 | 9.4 |

| | 1200 | | | | | 1400 | | | | | 1600 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 200 | 1.9 | 1.9 | 7.7 | 1.06 | 4.8 | 1.2 | 2.5 | 8.2 | 1.22 | 5.1 | 0.9 | 3.3 | 8.5 | 1.28 | 5.3 |
| 400 | 5.2 | 1.6 | 10.4 | 1.03 | 6.5 | 4.0 | 2.1 | 11.0 | 1.16 | 6.9 | 3.0 | 2.8 | 11.8 | 1.43 | 7.4 |
| 600 | 10.0 | 1.2 | 13.3 | 0.93 | 8.3 | 7.5 | 1.6 | 13.4 | 1.13 | 8.4 | 5.5 | 2.4 | 13.9 | 1.33 | 8.7 |
| 800 | 17.0 | 0.8 | 14.7 | 0.87 | 9.2 | 12.0 | 1.3 | 15.8 | 1.05 | 9.9 | 9.0 | 1.8 | 16.6 | 1.23 | 10.4 |
| 1000 | 25.0 | 0.4 | 16.2 | 0.85 | 10.1 | 19.5 | 0.8 | 17.0 | 0.97 | 10.6 | 13.0 | 1.2 | 18.4 | 1.17 | 11.5 |
| 1200 | 45.0 | 0.0 | 17.1 | 0.72 | 10.7 | 26.0 | 0.4 | 18.4 | 0.95 | 11.5 | 19.0 | 1.0 | 19.5 | 1.11 | 12.2 |
| 1400 | | | | | | 45.0 | 0.0 | 19.4 | 0.81 | 12.1 | 26.0 | 0.5 | 20.6 | 1.06 | 12.9 |
| 1600 | | | | | | | | | | | 48.0 | 0.0 | 21.1 | 0.86 | 13.2 |

| | 1800 | | | | |
|---|---|---|---|---|---|
| 200 | 0.6 | 4.0 | 9.0 | 1.39 | 5.6 |
| 400 | 2.4 | 3.8 | 12.3 | 1.50 | 7.7 |
| 600 | 4.5 | 3.3 | 14.4 | 1.49 | 9.0 |
| 800 | 7.0 | 2.7 | 17.0 | 1.44 | 10.6 |
| 1000 | 9.6 | 2.1 | 19.5 | 1.40 | 12.2 |
| 1200 | 13.2 | 1.6 | 20.8 | 1.34 | 13.0 |
| 1400 | 18.4 | 1.0 | 22.1 | 1.26 | 13.8 |
| 1600 | 26.4 | 0.5 | 22.7 | 1.18 | 14.2 |
| 1800 | 48.0 | 0.0 | 23.2 | 0.95 | 14.5 |

However, the feeds that research and experience have shown to be most suitable for horses provide more protein than, judging by Harvey's results, working horses require. Furthermore, the results reported by McCampbell (1912) indicate that high-protein rations result in increase in body weight, or at least in a reduction of weight loss, by working horses. In view of these facts, the protein allowances given in Table 1 for working horses are more liberal than the actual requirements as determined by Harvey.

It should be noted that determinations of protein requirements of animals made by Mitchell (1933) indicate that the protein requirement is 12.5 milligrams of protein per Calorie of basal heat production in young and mature animals of various species. Allowances made on this basis would exceed the allowances recommended in this bulletin for maintenance and growth, particularly those for rapidly growing colts.

*Protein Requirements of Pregnant Mares.*—Using Morrison's (1948) figures for birth weights of foals, and assuming that the figures cited by Brody (1945) on weight and protein content of the placenta and amniotic fluid of cattle are similar to those of horses, the protein content of the foal at time of birth, and of the amniotic fluid and the placenta, have been estimated as follows:

*Produced by Draft Mare (1800 pounds)*

| | Weight | Protein | |
|---|---|---|---|
| | *lbs.* | *per cent* | *lb.* |
| Foal at birth | 120 | 14.2 | 17.0 |
| Amniotic fluid | 49 | 3.4 | 1.7 |
| Placenta | 24 | 12.2 | 2.9 |
| Total | | | 21.6 |

At least half the fetal protein, or 10.8 pounds, is deposited during the last quarter of pregnancy. The mean daily increment is, therefore, 0.13 pound (10.8 ÷ 85 days equals 0.13 pound protein gained daily). An additional allowance must be made for metabolic activity of the fetus. In the absence of data on the protein requirements of the fetal animal for metabolic activity, an allowance for this purpose of one-tenth of the maintenance requirement of the mare has been provided. In the case of the fetus carried by an 1800 pound mare, this allowance is about 0.10 pound digestible protein. If the biological value of protein of the feed is assumed to be 50 per cent, the ration must be increased over the mare's maintenance requirement by 2 (0.13 + 0.10) or 0.46 pound digestible protein daily to supply the additional protein to be deposited in the fetus, integuments, and amniotic fluid, and for metabolic activity of the fetus. Then the total protein required in the feed of an 1800 pound draft mare during the last quarter of pregnancy equals the normal maintenance requirement of 0.95 pound plus 0.46 pound for the fetus or 1.41 pounds of digestible protein daily.

The accepted practice of keeping mares on a maintenance ration during all but the last quarter of pregnancy seems reasonable in view of the fact that fetal growth is extremely low during the first three-fourths of the pregnancy period.

*Protein Requirements of Lactating Mares.*—According to Morrison (1948) the daily milk yield of draft mares has been reported to be from 26 to 77 pounds, and an average of the composition of mares' milk has been found to be 2 per cent protein, 10.1 per cent T.D.N. and 1.1 per cent fat. If the daily milk production of a 1600 pound mare is 50 pounds, the daily secretion of milk protein is 1 pound, and assuming the biological value of ingested protein to be 50 per cent, the lactating mare must be allowed 2 pounds of protein daily above the maintenance requirement of 0.87 pound, or 2.87 pounds of digestible protein daily.

*Protein Requirements of Weaned Colts.*—Allowances for growing horses have been computed on the assumption that: (1) The biological value of digestible protein in the feed is 50 per cent; (2) Protein content of the foal at birth is the same as that of the calf, namely 14.2 per cent (Brody, 1945); (3) The relationship between age of the animal and its chemical composition is similar to that of the calf (Moulton, 1923); and (4) Maintenance requirements are about four times the protein equivalent of endogenous nitrogen metabolism (Brody, 1945). The following are examples of the method used in the calculation of the protein requirements of growing horses.

*Protein Requirements of a Growing Horse*
(Assumed mature weight, 1800 pounds)

| Body Weight | Age | Daily Gain | | Protein Required in Ration for Growth | Protein Required for Maintenance | Total Protein Required |
|---|---|---|---|---|---|---|
| | | Total | Protein | | | |
| *lb.* | *mos.* | *lb.* | *lb.* | *lb.* | *lb.* | *lb.* |
| 400 | 2.4 | 3.8 | 0.57 | 1.15 | 0.36 | 1.50 |
| 1000 | 9.6 | 2.1 | 0.35 | 0.70 | 0.70 | 1.40 |

Protein allowances for colts during rapid growth, calculated in this manner, are between those of Morrison (1948) and Mitchell (1947a); thus they represent, in effect, a compromise between the recommendations of these authors.

## MINERALS

Calcium, phosphorus, iodine and sodium chloride are known to be essential for normal growth and physiological functions of the horse and mule. Since magnesium is a normal constituent of bone, it would be expected that this is also a dietary essential for Equidae. On the basis of work with other species it would be expected that other mineral elements are essential and, until we have evidence to the contrary, it is a safe practice to consider them among the nutrients to be provided for horses and mules.

The proper development of the skeletal structures is particularly important in the horse and mule. The strain and stress on the skeletal structures of animals required to develop maximum energy outputs, such as the race horse running at its greatest speed or the draft horse under heavy loads, makes the mineral nutrition of the horse of paramount importance. The nutrient requirement of the thoroughbred trained and put on the race track at the early age of 2 years is probably higher than for horses that are more mature before being trained for work.

Very little is known about the relationship of nutrition to the etiology of various exostoses commonly seen in the horse such as spavins, ringbones and other bone diseases. Following the outbreak of equine osteomalacia in central Illinois (Law, 1911) the incidence of spavins, ringbones and other bone diseases was believed to be increased. Kintner and Holt (1932) reported that the admission rates of horses to army veterinary hospitals were much higher when the animals were fed a ration low in calcium than when the ration was supplemented with calcium. The incidence of various types of exostoses was higher among the horses on a calcium-deficient ration than on rations adequate with respect to this element.

*Calcium and Phosphorus.* –These minerals are especially important in the development of the skeletal structures of the animal. A condition in horses manifested by rarefaction or softening of the bone has been encountered in various parts of the world. The condition has been referred to in the literature by various names such as osteomalacia, osteoporosis, osteodystrophia fibrosa and other terms. It appears that the condition may be brought about by a deficiency of either calcium or phosphorus or by imbalance in the diet of these two elements. The widespread occurrence of the malady among army horses and mules in South Africa was described in 1906 by Lane. The etiology of the disease was not known at that time and by some it was thought to be of pathogenic origin. However, Lane was able to correct the condition by feeding a good ration.

TABLE 3

CALCIUM AND PHOSPHORUS ALLOWANCES FOR GROWING HORSES

Mature Weight in Pounds—Calcium Per Day

| Weight | 600 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 |
|---|---|---|---|---|---|---|---|
| *lbs.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* |
| 200 | 7.9 | 9.8 | 12.3 | 14.3 | 17.9 | 20.8 | 24.5 |
| 400 | 8.7 | 10.8 | 13.4 | 16.1 | 20.5 | 24.6 | 27.9 |
| 600 | 7.8 | 10.6 | 13.4 | 16.9 | 21.3 | 24.6 | 27.4 |
| 800 | | 9.7 | 9.8 | 15.3 | 20.1 | 24.9 | 27.0 |
| 1000 | | | 11.6 | 14.7 | 17.8 | 22.6 | 26.5 |
| 1200 | | | | 12.4 | 15.9 | 19.5 | 23.6 |
| 1400 | | | | | 14.1 | 16.8 | 21.1 |
| 1600 | | | | | | 15.3 | 18.3 |
| 1800 | | | | | | | 16.8 |
| | | | Phosphorus Per Day | | | | |
| 200 | 7.3 | 8.8 | 10.6 | 12.2 | 14.9 | 17.7 | 20.4 |
| 400 | 9.1 | 10.8 | 12.5 | 14.6 | 17.5 | 21.4 | 22.3 |
| 600 | 9.3 | 11.2 | 13.4 | 16.3 | 18.9 | 22.1 | 22.9 |
| 800 | | 10.9 | 10.3 | 15.3 | 18.7 | 23.3 | 23.9 |
| 1000 | | | 12.9 | 15.4 | 17.8 | 22.6 | 23.9 |
| 1200 | | | | 14.0 | 16.7 | 20.4 | 22.6 |
| 1400 | | | | | 15.8 | 19.6 | 22.0 |
| 1600 | | | | | | 17.2 | 20.6 |
| 1800 | | | | | | | 18.9 |

The characteristic symptoms of osteodystrophia fibrosa or osteomalacia have been described by Kintner and Holt (1932) as follows: "The disease develops gradually with an intermittent shifting lameness with no obvious cause, usually manifested by a characteristic shortening of the stride of either the front or hind legs or both. This lameness is increased by weight bearing; it may disappear on rest only to recur in some other joint. While standing the animal usually shifts its weight, thus resting affected parts. The shoulder and hip joints are involved commonly. As the disease progresses, the lameness becomes more marked and the stride exceedingly shortened. Some cases exhibit proliferative changes of the facial bones." Longitudinal striations indicating a decalcification process frequently occur in the compact portion of the metacarpal bone. Serum calcium levels are frequently low while there is an increase in the inorganic phosphorus.

Experimental osteodystrophia fibrosa was studied by Niimi (1927) and by Niimi and Aoki (1927) in Japan and by Sturgess and Crawford (1927) in India. These workers produced the disease by feeding rations low in calcium and high in phosphorus. The disease occurred in the Philippine Islands on a ration providing 12.9 grams of calcium and 22.0 grams of phosphorus daily, according to Kintner and Holt (1932). These workers emphasized the ratio of calcium to phosphorus as an important factor in the production of the disease. It is of some significance that the incidence of the disease in the Philippine Islands was found to be about three times higher in horses than in mules on similar dietary regimens.

While some data are available on the requirements of the horse for calcium and phosphorus, there are wide variations in the figures. The requirements are undoubtedly higher for the young growing animal than for the mature animal. Studies on the inorganic phosphorus content of the blood of growing horses (Pearson, 1934) show that the level at birth is around 5.3 mg. per 100 ml. of serum and that by the time maturity is reached, the level has declined to about 3.4 mg. per 100 ml. of serum. Calcium levels vary less with age. The normal for mature horses ranges between 12 and 13.5 mg. per 100 ml. of serum. On the basis of these data and calculated retentions, it is apparent that young growing animals require a higher proportion of calcium and phosphorus in their diet than do mature animals.

TABLE 4

COMPOSITION OF CALCIUM AND PHOSPHORUS SUPPLEMENTS

| Mineral Supplement | Calcium | | Phosphorus | |
|---|---|---|---|---|
| | % | *gm./lb.* | % | *gm./lb.* |
| Bone meal, raw, feeding | 22.7 | 103 | 10.1 | 46 |
| Bone meal, steamed | 30.0 | 136 | 13.9 | 63 |
| Defluorinated superphosphate | 28.3 | 128 | 12.3 | 56 |
| Dicalcium phosphate | 26.5 | 120 | 20.5 | 93 |
| Disodium phosphate | | | 8.6 | 39 |
| Limestone | 38.3 | 174 | | |
| Monocalcium phosphate | 16.0 | 72 | 24.0 | 109 |
| Monosodium phosphate | | | 22.4 | 102 |
| Oyster shell flour | 36.9 | 167 | | |
| Spent bone black | 22.0 | 100 | 13.1 | 59 |

The requirements of the growing colt have been estimated by Harvey, et al. (1944) at 25 grams each per day for calcium and phosphorus. This is considerably higher than the levels proposed by Schuenert (1923) or by Mitchell (1947b) who estimates that a 400 pound colt requires about 19 grams of calcium and 13 grams of phosphorus. This would be equivalent to about 0.42 per cent of calcium and 0.29 per cent of phosphorus in the ration on a dry basis. The requirements on a percentage basis decrease as the animal matures (Table 3).

Information on the effect of work on the requirements for minerals is very meager. Harvey and associates (1943) measured the effect of hard work on the retention of calcium and phosphorus. They reported that various amounts of work did not seem to affect significantly either the calcium or phosphorus balances of horses.

The composition of the more common calcium and phosphorus supplements is shown in Table 4.

*Salt.* —Sodium, potassium and chlorine are all known to be essential for the normal physiological performance of the animal. Potassium is normally present in plants in amounts sufficient to meet the needs of herbivorous animals. The amounts of sodium and chlorine present in feeds of plant origin tend to be rather low. The common salts of sodium and potassium are freely soluble and readily absorbed from the intestine. The excretion of sodium chloride by the renal pathway follows very closely the amount ingested. No provision is made for storing appreciable amounts of sodium chloride. When the intake is low the excretion is reduced to a very low level in an apparent effort to conserve the meager supply for vital functions. Large amounts of sodium chloride may be lost from the body through perspiration, especially by horses at hard work during hot weather. The amount of sodium chloride that may be lost through perspiration by horses and mules is unknown, but on the basis of data on human beings it must be considerable.

A deficiency of sodium chloride in human beings is accompanied by anorexia and nausea. Miners after profuse sweating frequently develop cramps if they drink large amounts of water without added salt to replace that lost from the body. An acute salt deficiency that may be brought on by a low intake and copious sweating is accompanied by fatigue and exhaustion (McCance, 1936). A deficiency of salt over a longer period of time results in lowered efficiency in utilization of proteins (McCance, 1936; Terroine and Reichert, 1930).

Horses subjected to heavy work, especially during hot weather, should be provided with adequate salt and should be allowed to drink what water they desire at intervals of about one hour. After they have been worked hard for three or four hours they should not be allowed to drink all the water they want while they are still hot and sweating.

The quantitative requirements of horses for salt have not been accurately established, and it is probable that they may consume more than enough to meet their needs if they have free access to it. Since the requirements vary so widely, depending on the amount of work performed and the temperature, the best plan is to supply salt *ad libitum* to horses so that they can consume what they want. It may be provided either as flake salt or in block form. Horses having free access to flake salt consumed about 50 grams daily per head (Hudson, 1926) while mules used for heavy farm work consumed only about 11 grams per 1000 pounds of body weight when they were fed block salt (Templeton, 1928).

*Iodine.*—A small amount of iodine is essential for reproduction and normal physiological processes. Iodine exerts its physiological effects through the thyroid gland as the hormone thyroxine. Visible evidence of iodine deficiency occurs most frequently in newborn foals which are frequently born dead or, if alive, are weak and unable to stand to nurse. The breathing may be labored and the pulse rate high.

In widely distributed areas of the world and especially in high mountainous regions, soils, plants and water are very low in iodine. The iodine-deficient areas of the United States include sections of the states of Wisconsin, Ohio, Iowa, Indiana, Illinois, Michigan, Montana, Nebraska, New

York, the Dakotas, Utah, Nevada, Colorado, Oregon, California and Washington.

The most effective means of supplying iodine to horses in proper amounts is through the salt. The iodine requirements of various species have been reviewed by Griem, et al. (1942). On the basis of the recommendation of the Study Committee on Endemic Goiter of the American Public Health Association, iodized salt is now formulated with one part of potassium iodide in 10,000 parts of salt. This is 0.01 per cent of potassium iodide or 0.0076 per cent iodine. The feeding of salt iodized at this level would normally furnish several times the iodine requirement for pregnant mares.

FIG. 1. Newborn weak colt affected with simple goitre due to deficiency of iodine during prenatal period. (Courtesy of the Western Washington Agricultural Experiment Station.)

*Other Essential Minerals.*—Other elements, particularly cobalt and copper, are known to be dietary essentials for cattle and sheep. There are well defined areas in various parts of the world where the quantities of these elements in the natural feeds are insufficient to permit successful production of cattle and sheep without supplementation of one or both of these elements.

There are no authentic reports of horses suffering from a deficiency of cobalt even in areas where the condition is endemic. Filmer (1933) reports that in Western Australia horses are not susceptible to enzootic marasmus. It appears that either cobalt is not a dietary essential for horses or their requirements are much lower than those of cattle or sheep.

Bennetts and Beck (1942) in their discussion of enzootic ataxia, a disease occurring in lambs in Western Australia due to a deficiency of copper, suggest that foals in this area may show abnormal manifestations. The clinical features observed in foals are malnutrition and abnormalities in structure and posture of the limbs.

*Selenium Toxicity.*—A condition known as "alkali disease" has been a problem of considerable importance for many years in sections of the Great Plains area of the United States and in various other parts of the world.

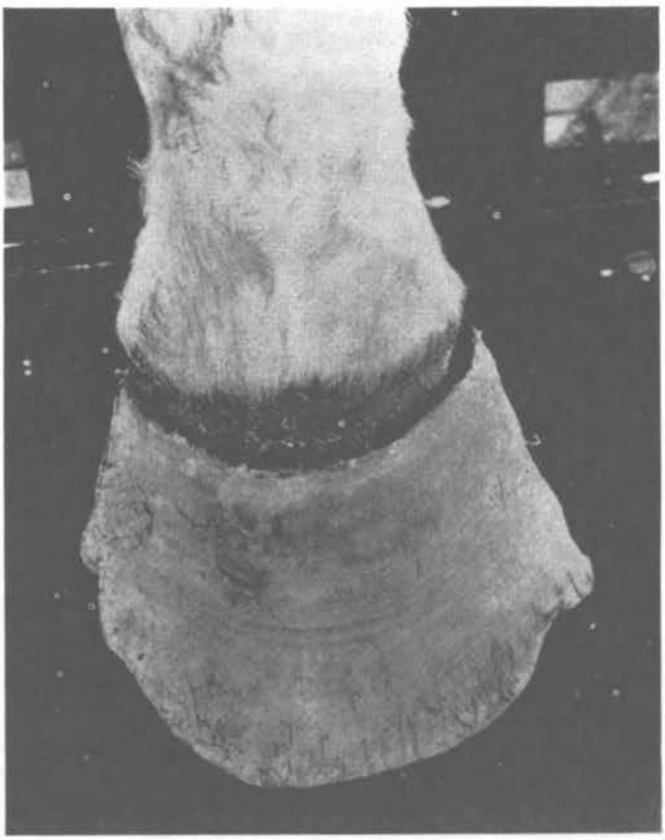

FIG. 2. The separation of the hoof from the foot of a horse that died after it had been on seleniferous feeds for only eight weeks. (Courtesy of the South Dakota Agricultural Experiment Station.)

The malady was first reported among horses in 1856 by Madison (1860), an army surgeon stationed at Fort Randall, in what was then the Territory of Nebraska. There is reason to believe that Marco Polo encountered the disease in his travels on the frontier of China (Moxon, 1937). More recently the disease has been studied by Moxon (1937).

The condition in horses now known to be due to selenium poisoning has been referred to as blind staggers, alkali disease, and by other local terms. The characteristic symptoms of selenium toxicity in horses are loss of the long hair from the tail and mane. Frequently a ring appears on the wall of the hoof below the coronary band and in more advanced cases the hoof gradually separates from the foot and may be sloughed off. Colts are sometimes born with deformed hoofs. In the terminal stage blindness and varying degrees of paralysis may occur. Chronic selenium toxicity occurs when animals consume feed containing from 5 to 40 micrograms of selenium per gram on a dry basis. While recent work suggests that the toxicity of selenium may be counteracted by feeding small amounts of arsenic (DuBois, et al., 1940; Moxon and Rhian, 1943) this is still in the experimental stage so far as horses are concerned.

*Other Toxic Elements.*—There have been reports of maladies in horses that have been attributed to an excess of other mineral elements. Fluorine may occur in untreated rock phosphates in amounts sufficient to be toxic to other species. While no experimental information is available on the toxicity of fluorine for the horse, the feeding of rock phosphate should be avoided.

It has recently been suggested (Carlström and Hjärre, 1938) that an excess of manganese may be the cause of a condition known as "forage anemia" which occurs in natural forest pastures of Scandinavia and Finland. Affected animals show signs of anemia, decreased blood volume and low red cell count. Edema and emaciation occur in spite of good appetite. The pastures in these areas are frequently very high in manganese. However, feeding experiments have not substantiated the theory that forage anemia is due to an excess of manganese.

## Vitamins

Information on the quantitative vitamin requirements of the horse is very meager and the question as to whether or not certain vitamins are required at all by Equidae has yet to be answered. The horse is a monogastric herbivorous animal and it would not, therefore, be surprising if it differs from ruminants in respect to its requirements for some of the B vitamins. On the basis of present information it would appear that the nutrition and feeding of horses with respect to vitamins is less of a problem than it is with some other domestic animals. However, this impression may be due to the meager amount of information available on the nutritional requirements of the horse.

*Carotene.*—Carotene is the precursor of vitamin A and is the form in which this factor occurs in natural feeds consumed by horses. Horses on good quality pasture may consume many times the amount of carotene necessary for their daily requirements. The animal has the ability to convert the carotene to vitamin A and to store relatively large amounts of it in the liver. Vitamin A *per se* is supplied in cod liver oil or other fish oils.

The amount of carotene present in forage is 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

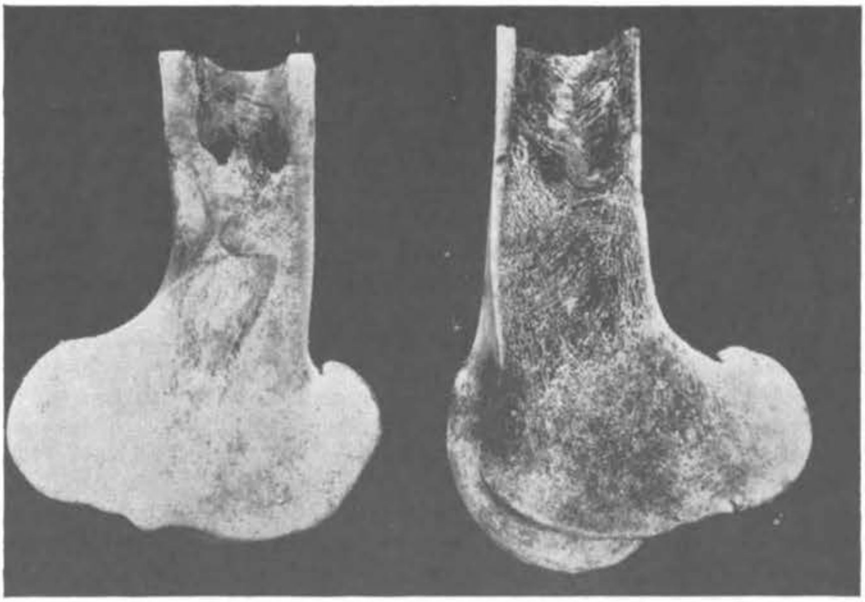

FIG. 3

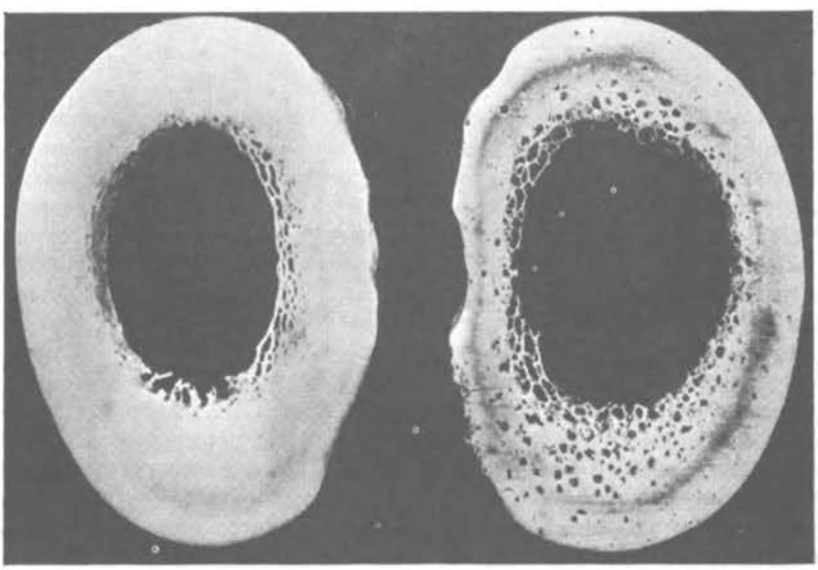

FIG. 4

FIGS. 3 and 4. The effect of a vitamin A deficiency on the bones of a horse. Figure 3, right, shows sagittal section of the distal end of femur of deficient animal compared to normal bone (left). Figure 4, right, shows cross section of cannon bone from deficient animal compared with normal bone on the left. (Courtesy of the California Agricultural Experiment Station.)

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.

The effects of a vitamin A deficiency in horses have been studied by Howell, et al. (1941), Schmidt (1948) and Klemola (1933). The deficiency is characterized by night blindness, lacrymation, 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 exuberance similar to increased scaling of epidermis. That the leg bones may be affected is indicated by failure of mineralization of the Haversian systems of these bones. A deficiency of vitamin A does not appear to be the cause of the joint lesions that are sometimes encountered in horses (Hart, et al., 1943; Callender and Kelser, 1938).

The quantitative requirements of the horse for vitamin A have been studied by Guilbert, et al. (1940). Allowances are in terms of carotene because it is the precursor of vitamin A and the form available in the feeds ordinarily consumed by horses. Levels of 1.4 to 1.5 mg. of carotene per 100 pounds of body weight are reported to meet the minimum daily requirements of the horse (Guilbert, et al., 1940). This level probably does not allow for adequate storage nor does it meet the demands for reproduction and other special functions. For this reason the allowances recommended for both growing and mature horses are on the basis of 5.0 mg. per 100 pounds of body weight per day. This should be sufficient to build up and maintain body reserves and to meet the various physiological functions such as reproduction and lactation.

*Vitamin D.*—Under normal farm conditions, where horses are worked regularly and are exposed to sunshine, they probably do not need added amounts of vitamin D. Where they are confined or where exposure to sunshine is restricted, or if they are fed for rapid growth and development of bone such as for racing at an early age, there may be some basis for supplying extra amounts of vitamin D. Experimental information on the requirements of the horse for vitamin D is not available. On the basis of information on other species 300 I. U. of vitamin D per 100 pounds of live weight daily should be adequate to meet the needs of horses.

*B Vitamins.*—Evidence that some of the B vitamins may be dietary essentials for the horse was first presented by Naito, et al. (1925). Carlström and Hjärre (1939) reported that horses fed rations deficient in the B vitamins became emaciated and developed anorexia and incoordination of movements. Evidence supporting the earlier observations that horses require at least some members of the B vitamins has been reported by Pearson, et al. (1944a).

The synthesis in the intestinal tract of the horse of considerable amounts of thiamine, riboflavin, pantothenic acid, nicotinic acid, pyridoxine, folic acid and biotin has been demonstrated by Carroll, Goss and Howell (1949). Since most of the synthesis of the B vitamins apparently occurs in the caecum, it is doubtful if they are absorbed to any extent. Horses fed a ration containing 90 micrograms of thiamine per pound of feed for 19 weeks lost weight, became nervous, showed incoordination of the hind quarters and responded to the administration of synthetic thiamine (Carroll, Goss and Howell, 1949).

It has been estimated on the basis of growth and excretion studies with Shetland ponies that 2.0 mg. of riboflavin per 100 pounds of body weight daily meets the requirements of the horse for this vitamin (Pearson, et al., 1944a; Pearson, et al., 1944b). Jones (1945) has presented evidence suggesting that iridocyclitis or periodic ophthalmia may be due to a deficiency of riboflavin. The symptoms encountered are lacrymation, exudate of the anterior chamber and ptosis. In advanced stages cataracts, vitreous opacities and retinal detachment may occur. More recently it has been reported (Jones, et al., 1946) that the administration of large doses of riboflavin is ineffective in curing periodic ophthalmia, but there is evidence that low riboflavin diets result in a higher incidence of the disease. Further work is needed before any conclusions can be drawn as to the exact relationship of riboflavin to periodic ophthalmia.

Evidence has been presented indicating that nicotinic acid is synthesized by the horse (Pearson and Luecke, 1945; Huff, et al., 1946). It was found that horses made normal gains on rations that provided approximately 0.10 mg. of nicotinic acid per kilogram of body weight per day. When the daily intake was reduced to 0.01 mg. per kilogram of body weight the amount excreted in the urine and feces each exceeded the intake. This could be accounted for only on the basis of synthesis since the animals were gaining weight. It is of interest from a comparative biochemical standpoint that the chief end product of nicotinic acid metabolism in the horse is not N'methylnicotinamide as in the dog, man or rat. Recently it has been shown that the horse can convert dietary tryptophan to nicotinic acid (Schweigert, et al., 1947). It would, therefore, be expected that the need of the horse for a dietary source of nicotinic acid may be influenced by the amount of tryptophan in the diet.

Urinary excretion studies with horses definitely show that the amount of pantothenic acid excreted by the renal pathway varies with the amount ingested (Pearson and Schmidt, 1948). Shetland ponies on a daily intake of approximately 40 micrograms per kilogram of body weight appeared to be equally 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 pantothenic acid.

The amounts of some of the B vitamins in mares' colostrum and milk have been studied by Pearson (1947). The information is of interest from a comparative standpoint and may find application in feeding orphaned foals. The colostrum was found to contain an average of 38 micrograms of thiamine, 138 micrograms of riboflavin, 160 micrograms of nicotinic acid and 747 micrograms of pantothenic acid per 100 ml. The corresponding values for the milk were 16, 40, 50, and 331 micrograms per 100 ml. for the respective vitamins. The colostrum is richer in all of the four vitamins than is milk. It is of interest that cow's milk is richer in each of the four vitamins than mare's milk.

*Other Vitamins.*—The need for a dietary source of tocopherol or vitamin

E in the rations of horses has not been demonstrated experimentally, and there is little evidence to substantiate the use of vitamin E in the treatment of sterility in horses. Vogt-Möller (1939) reported negative results from vitamin E therapy in the treatment of mares suffering from early or late abortion. Furthermore, vitamin E is widely distributed in the feeds normally consumed by horses.

There is no evidence to indicate that ascorbic acid is a dietary essential for the horse. Following the ingestion of synthetic ascorbic acid by the horse, less than 2 per cent was found to be excreted in the urine (Pearson, et al., 1943) and since much larger amounts than this are recovered when it is administered intravenously, the evidence suggests that there is considerable destruction of this vitamin in the digestive tract. Following an investigation on ascorbic acid therapy in the treatment of mares with irregular breeding records, Davis and Cole (1943) concluded that additional data were necessary before any conclusions could be drawn.

It is of interest to note that the ascorbic acid content of mare's milk is about five times that of cow's milk. The reduced ascorbic acid content of mare's milk is around 12 mg. per 100 ml. (Pearson, 1947).

*Other Nutritional Disturbances.*—A condition commonly referred to in horses as "Founder" has been known for a long time. The condition occurs in horses after they have eaten large amounts of grain. The characteristic symptoms of the disease are muscle tremors, anorexia, increased respiratory rate, lesions of the hoof, fever and frequently death. The physiological disturbances characteristic of the condition have been investigated by Åkerblom (1934) who found it possible to reproduce the disease by the administration of 10 grams of histidine together with a culture of B. coli. The B. coli apparently decarboxylates the histidine to form histamine which was found in the gastrointestinal contents of affected horses. Typical symptoms of the disease could be produced by the intravenous or subcutaneous administration of histamine. The disease appears to be due to the absorption of histamine which arises from the histidine of the ingested grains. The formation of histamine is apparently dependent on the action of microorganisms in the gastrointestinal tract.

## Feeds for Horses

*Approximate Composition of Rations.*—Since there is a wide variation in the weights of different breeds of horses, age is a better criterion of the percentage of various nutrients that should be provided in the ration than is weight. While the percentage of protein in rations for growing colts up to one year of age would be essentially the same for Shetland ponies and Percherons, there would be a great difference in the amounts of the various nutrients required. From a practical standpoint rations would probably be prepared for horses at work, during pregnancy, with nursing foals and for growth, and appropriate amounts fed according to size.

Table 5 shows the approximate percentage of T.D.N. digestible protein, calcium and phosphorus for different classes of horses. For mature horses for maintenance, light or medium work the percentage of T.D.N. should be about 62.5 and digestible protein about 4.8. The amounts of ration for horses of different ages and weights are shown in Tables 1 and 2. Rations made up with the approximate percentage composition shown in Table 5 and appropriate amounts fed according to size would provide approximately the amounts of T.D.N. and digestible protein shown in Tables 1 and 2. For horses doing very hard work the percentage of T.D.N. in the ration needs to be higher. This is normally accomplished by increasing the proportion of concentrates to roughage.

For mares during the last quarter of pregnancy the percentage of T.D.N. and digestible proteins needs to be higher than for horses doing light work. The amounts of these nutrients for mares during lactation needs to be still higher. Normally this will be accomplished by using a higher proportion of concentrates and protein-rich feeds. For colts up to one year of age the digestible protein content of the total ration should be not less than 10 per cent. This would include that portion of the ration supplied as milk. Since milk contains a much higher percentage of protein (dry basis) than this, the concentrate mixture fed to colts could normally be the same as that fed to mares during lactation.

TABLE 5

APPROXIMATE PERCENTAGE OF T.D.N., DIGESTIBLE PROTEIN, CALCIUM AND PHOSPHORUS IN RATIONS FOR HORSES

(Based on air dry feed containing 90 per cent dry matter)

| Class of Horses | Digestible Protein | Total Digestible Nutrients | Calcium | Phosphorus |
|---|---|---|---|---|
| | % | % | % | % |
| Mature horses: | | | | |
| Maintenance | 4.9 | 62.5 | 0.17 | 0.19 |
| Light work | 4.8 | 62.5 | 0.17 | 0.19 |
| Medium work | 4.8 | 62.5 | 0.16 | 0.18 |
| Hard work | 4.7 | 66.7 | 0.16 | 0.18 |
| Last quarter of pregnancy | 5.3 | 62.2 | 0.20 | 0.20 |
| Lactating mares | 8.2 | 71.4 | 0.22 | 0.20 |
| Growing horses: | | | | |
| Up to 1 year | 10.3 | 62.5 | 0.38 | 0.33 |
| 1 to 2 years | 6.0 | 62.5 | 0.23 | 0.23 |
| 2 to 3 years | 5.2 | 62.5 | 0.19 | 0.20 |

*Feeding Light Horses.*—Saddle horses and other light horses vary so much in size, type, temperament and the amount of work (riding, driving) done that it is difficult to state just how much feed is required. Usually they require less feed in proportion to their weight than draft horses.

In general, the requirements for horses ridden or driven are as follows:

up to one hour per day—maintenance ration
from one to three hours per day—ration for light work
from three to five hours per day—ration for medium work
from five to eight hours per day—ration for hard work

*Feed Combinations.*—The nutritional requirements of horses may be met with a variety of combinations of feed. Practices vary with the feeds available within a region and the characteristics of these feeds. The nutritive value of a particular feed varies somewhat with the conditions under which it is produced, fertilization, weather, method of harvesting, method of storage and length of storage. Modern processing has produced feeds which may be either higher or lower in nutritive value than the original feed. Some oat mill feeds consist to a considerable extent of hulls with associated residues of other constituents of the grain; alfalfa leaf meals on the other hand represent a direct concentration of nutritive value through removal of the stems, and good silage, especially young grass silage, tends to preserve many of the characteristics of fresh grass.

The special nutritive value of the forages lies in the leaves. The proportion of leaf to stem is important. The protein, calcium and vitamin content is high in plants with a large proportion of leaves. Many leaf meals are in effect protein concentrates. The green color of the leaves is a fair index of the carotene content of a forage, but this index fails when the leaf has been stored for long periods of time under even the best of practical conditions.

During part of the year horses are on pasture. Pasture grasses are often a general corrective of the deficiencies of grains and hay, either inherent or through storage or processing. Pasture grasses vary in nutritive and supplementary value with kind and state of maturity. The young grasses and legumes are relatively rich in protein and calcium while older grasses or those that develop stem rapidly are less valuable for such nutrients both because of lower concentration and digestibility.

Experience tends to make feeding practices fairly uniform within an area, although they may vary with the specialized crops on individual farms. The problem in feeding animals is to make the best use of the feeds available on the farms with the minimum of purchased feed. The effect of the advance in knowledge of nutrition and the composition of feeds has been to widen the range of feeds from which selections may successfully be made, to point the way to possible reasons for failure, and to broaden the source of supplements available to correct deficiencies.

Feeds of the same kind tend to be similar in nutritive value and as a first approximation can be substituted one for another in the ration. Within a type, however, there are considerable differences—as to both nutritive value and suitability for feeding horses. Oats appear to be particularly suitable for horses because they provide sufficient bulk, along with energy, protein, and phosphorus, to prevent impaction when it is the major feed. Supplementing oats with hay of low leaf content may result in too bulky a ration or in an insufficient energy intake for work. The quantity of oats that may be fed can be increased through the use of reduced quantities of leafy hay. Hays low in calcium or protein may be supplemented with bone meal or limestone and with protein concentrates. Old hays and hays that have lost their nutritive value in harvesting may be supplemented with new hay, leaf meals, or, in the case where only carotene is low, good silage.

*Pasture and Roughage.*—The natural feed and best source of nutrients for horses is pasture. With the addition of limited amounts of concentrates for foals, brood mares, and horses at hard work, good pasture provides all the nutrients horses need. Not only is it the least expensive feed for horses, but its use involves a minimum of labor. Horses worked throughout the day should be pastured at night during hot weather, not only for the sake of economy, but because they are more thrifty on pasture and cooler than in stalls. While bluegrass or other permanent pasture is excellent for use in early spring and fall, a mixture of grass and legumes is superior to grass alone.

Unlike ruminants, horses are likely to consume an excess of roughage since the comparatively small stomach of the horse limits its capacity. Digestive disturbances are likely to result from a digestive tract unduly distended with roughage, especially when the horse is working hard. For horses doing hard work, the amount of hay fed should be limited, especially if it is palatable, and it should be fed mostly at night when the animal has sufficient time for its mastication and digestion.

The proportion of roughage in the rations of horses may be varied considerably depending on the quality of the roughage, the condition of the animal and the output of energy by the animal. The horse can utilize large amounts of roughage when fed for maintenance and a low level of energy production, provided the roughages are of good quality. For wintering farm work horses, entirely satisfactory rations may consist of legume hay, of grass hay plus some legume, or of a coarse roughage plus some legume hay. Where only coarse or inferior quality roughages are available, supplementation with other feeds to provide proteins, minerals and vitamins will be needed. Good pasture may be used as the entire ration both for idle horses and for growing stock after the first year. For maximum rates of growth, roughage or pasture rations must be supplemented with concentrates. Dawson, et al. (1945) showed that feeding young animals from one to three years of age on Western range forages without other feeds delayed maturity and stunted the skeletal development.

That the horse digests the fiber portions of feeds less efficiently than ruminants has been demonstrated by Woodman (1930). Increasing the amount of fiber in the ration also affects the digestibility of other nutrients (Axelsson, 1941; Earle, 1948). Work by the Bureau of Animal Industry (Earle, 1948) has shown that decreasing the crude fiber content of the ration from 27 per cent to 8 per cent resulted in an increase in the digestibility of the protein from 60 to 80 per cent, the digestibility of the nitrogen-free extract from 62 to 87 per cent and of the fat from 50 to 80 per cent. From this it is apparent that roughage fed at high levels may decrease the efficiency of utilization of the various nutrients of the ration. The minimum roughage requirements of horses according to Earle, et al. (1943) is between 0.4 and 0.5 per cent of the body weight.

The maximum amount of hay usually allowed a work horse is 1 to 1½ pounds of hay per 100 pounds of live weight. The total dry matter fed a 1000 pound working horse can be as little as 15 or as much as 24 pounds, while an idle horse of this same weight can safely be fed as little as 12 pounds of dry matter. Since individual variations in stomach capacity exist, it is necessary to observe the individuals carefully to make sure that each is receiving enough, and not too much, roughage.

Timothy hay is considered the standard roughage for horses in the northern part of the United States and in eastern Canada, and since the protein content of timothy hay is relatively low, it must be supplemented with concentrates when fed to foals and brood mares. In the western part of the

## TABLE 6
### Composition of Feeds[1]

| | Dry Matter | Digestible Protein | Total Digestible Nutrients | Calcium | | Phosphorus | |
|---|---|---|---|---|---|---|---|
| | % | % | % | % | gm./lb. | % | gm./lb. |
| Air-dried forages: | | | | | | | |
| Alfalfa hay, average | 90.5 | 10.5 | 50.3 | 1.47 | 6.67 | 0.24 | 1.09 |
| Barley hay | 90.8 | 4.0 | 51.9 | 0.26 | 1.18 | 0.23 | 1.04 |
| Barley straw | 90.0 | 0.7 | 42.2 | 0.32 | 1.45 | 0.11 | 0.50 |
| Clover hay, crimson | 89.5 | 9.8 | 48.9 | 1.23 | 5.58 | 0.24 | 1.09 |
| Clover hay, red | 88.1 | 7.1 | 52.2 | 1.35 | 6.13 | 0.19 | 0.86 |
| Corn fodder, very dry | 91.1 | 3.8 | 58.8 | 0.24 | 1.09 | 0.16 | 0.73 |
| Corn stover, very dry | 90.6 | 2.1 | 51.9 | 0.29 | 1.32 | 0.05 | 0.23 |
| Cowpea hay | 90.4 | 12.3 | 51.4 | 1.37 | 6.22 | 0.29 | 1.32 |
| Kafir fodder, very dry | 90.0 | 4.5 | 53.6 | 0.35 | 1.59 | 0.18 | 0.82 |
| Lespedeza hay, average | 89.2 | 6.4 | 47.5 | 0.98 | 4.45 | 0.18 | 0.82 |
| Oat hay, moderately green | 88.1 | 4.9 | 47.3 | 0.21 | 0.95 | 0.19 | 0.86 |
| Oat straw | 89.7 | 0.7 | 44.7 | 0.19 | 0.86 | 0.10 | 0.45 |
| Prairie hay, moderately green | 90.7 | 2.1 | 49.6 | 0.36 | 1.63 | 0.18 | 0.82 |
| Reed canary grass | 91.1 | 4.8 | 45.1 | 0.33 | 1.50 | 0.16 | 0.73 |
| Sorghum fodder | 88.8 | 3.3 | 52.4 | 0.34 | 1.54 | 0.12 | 0.54 |
| Soybean hay | 88.0 | 9.6 | 49.0 | 0.94 | 4.27 | 0.24 | 1.09 |
| Sudan grass hay | 89.3 | 4.3 | 48.5 | 0.36 | 1.63 | 0.26 | 1.18 |
| Timothy hay | 89.0 | 2.9 | 48.9 | 0.23 | 1.04 | 0.20 | 0.91 |
| Silages, roots, tubers: | | | | | | | |
| Alfalfa silage, slightly wilted | 36.0 | 4.1 | 21.3 | 0.51 | 2.32 | 0.12 | 0.54 |
| Carrots | 11.9 | 0.9 | 10.3 | 0.05 | 0.23 | 0.04 | 0.18 |
| Corn silage, well matured, average | 27.4 | 1.2 | 18.1 | 0.10 | 0.45 | 0.06 | 0.27 |
| Sorghum silage, sweet | 25.3 | 0.08 | 15.8 | 0.08 | 0.36 | 0.04 | 0.18 |
| Soybean silage | 24.8 | 2.9 | 14.6 | 0.34 | 1.54 | 0.09 | 0.41 |
| Grains, seeds, and by-product concentrates: | | | | | | | |
| Barley | 89.4 | 10.0 | 77.6 | 0.09 | 0.41 | 0.47 | 2.13 |
| Barley (Pacific Coast) | 89.0 | 7.7 | 77.2 | 0.06 | 0.27 | 0.41 | 1.86 |
| Beet pulp, dried | 90.1 | 4.3 | 67.8 | 0.71 | 3.22 | 0.12 | 0.54 |
| Beet pulp, wet | 11.6 | 0.8 | 8.8 | 0.09 | 0.41 | 0.01 | 0.04 |
| Brewers' grains, dried (18–23% protein) | 92.3 | 16.8 | 61.7 | 0.29 | 1.31 | 0.48 | 2.18 |
| Brewers' grains, dried (23–28% protein) | 92.9 | 22.1 | 67.1 | 0.25 | 1.14 | 0.49 | 2.22 |
| Blood meal or dried blood | 91.8 | 60.0 | 61.3 | 0.33 | 1.50 | 0.25 | 1.14 |
| Citrus pulp | 90.1 | 2.5 | 74.4 | 2.28 | 10.35 | 0.17 | 0.77 |
| Coconut oil meal, expeller | 92.6 | 17.4 | 80.8 | 0.12 | 0.54 | 0.62 | 2.81 |
| Corn, yellow, No. 2 equivalent | 85.0 | 6.6 | 80.0 | 0.02 | 0.09 | 0.27 | 1.22 |
| Corn and cob meal | 86.1 | 5.3 | 73.2 | | | 0.22 | 1.00 |
| Corn gluten feed | 91.1 | 22.9 | 76.2 | 0.40 | 1.82 | 0.82 | 3.72 |
| Corn gluten meal | 91.4 | 36.5 | 80.3 | 0.20 | 0.91 | 0.41 | 1.86 |
| Cottonseed, whole pressed cake | 93.5 | 20.3 | 59.8 | 0.15 | 0.68 | 0.77 | 3.50 |
| Cottonseed meal (38–43% protein) | 92.2 | 34.2 | 73.5 | 0.18 | 0.82 | 1.14 | 5.18 |
| Distillers' corn grains, dried | 92.9 | 20.7 | 82.5 | 0.23 | 1.04 | 0.60 | 2.72 |
| Hominy feed | 89.7 | 7.5 | 81.4 | 0.05 | 0.23 | 0.48 | 2.18 |
| Kafir | 89.5 | 9.1 | 80.7 | 0.04 | 0.18 | 0.35 | 2.04 |
| Linseed meal (33% protein) | 91.2 | 30.0 | 76.6 | 0.44 | 1.99 | 0.94 | 4.26 |
| Linseed meal (37% protein) | 90.9 | 33.0 | 77.4 | 0.49 | 2.22 | 0.89 | 4.03 |
| Milo | 89.4 | 8.8 | 80.1 | 0.03 | 0.14 | 0.27 | 1.22 |

TABLE 6—*Concluded*

| | Dry Matter | Digestible Protein | Total Digestible Nutrients | Calcium | | Phosphorus | |
|---|---|---|---|---|---|---|---|
| | % | % | % | % | gm./lb. | % | gm./lb. |
| Milo head chops | 90.0 | 7.7 | 77.2 | 0.14 | 0.63 | 0.26 | 1.18 |
| Molasses, cane | 74.0 | | 54.0 | 0.74 | 3.35 | 0.08 | 0.36 |
| Oats | 90.2 | 9.4 | 72.2 | 0.09 | 0.41 | 0.43 | 1.95 |
| Oats (Pacific Coast) | 90.2 | 7.0 | 72.2 | 0.09 | 0.41 | 0.43 | 1.95 |
| Peanut oil meal (43% protein) | 92.8 | 39.2 | 81.8 | 0.16 | 0.73 | 0.54 | 2.45 |
| Rice bran | 91.0 | 8.7 | 68.4 | 0.08 | 0.36 | 1.36 | 6.17 |
| Rice polish | 90.3 | 9.6 | 82.6 | 0.04 | 0.18 | 1.10 | 4.99 |
| Rye | 89.5 | 9.9 | 75.7 | 0.01 | 0.04 | 0.43 | 1.95 |
| Soybeans | 90.0 | 33.7 | 85.7 | 0.27 | 1.22 | 0.62 | 2.81 |
| Soybean oil meal (hyd. or exp.) | 90.6 | 36.2 | 78.8 | 0.28 | 1.27 | 0.61 | 2.77 |
| Soybean oil meal (solvent extracted) | 90.6 | 42.4 | 78.4 | 0.29 | 1.32 | 0.63 | 2.86 |
| Wheat | 90.0 | 12.8 | 79.8 | 0.05 | 0.22 | 0.41 | 1.86 |
| Wheat (Pacific Coast) | 89.2 | 8.3 | 79.2 | 0.05 | 0.22 | 0.29 | 1.32 |
| Wheat bran | 89.7 | 13.3 | 66.2 | 0.14 | 0.63 | 1.30 | 5.90 |

[1] The Committee on Animal Nutrition is indebted to Professor F. B. Morrison for use of data from the 21st Edition of *Feeds and Feeding* on the composition of roughages and silages presented in this table. The data on the composition of concentrates was compiled by the Committee on Feed Composition of the National Research Council. The digestion coefficients used in calculating the digestible protein and T.D.N. of the concentrates were also taken from the 21st Edition of *Feeds and Feeding*.

United States, cereal hays, about equal to timothy hay as horse feed, are used extensively. Corn fodder and corn stover, if of good quality, are nearly equal in feed value to tomothy hay for horses.

The widespread prejudice against legume hay for horses is not well founded but seems to be based partly on the fact that when it is fed in unlimited amounts horses will gorge themselves on it, and partly on the fact that legume hay of poor quality actually is harmful and should not be used. Legume hay, which is more concentrated than timothy, should be fed in smaller amounts than the latter. Straw can be used successfully as a feed for idle horses provided some concentrate is fed with it, but it is considered unsuitable for horses at hard work because of its low energy value as a feed.

*Concentrates.*—Oats are considered almost an ideal feed for horses. They are less concentrated than other grains due to their bulky hulls, they form a loose mass in the stomach while other feeds tend to pack, and they are less likely to cause trouble if the horse has an opportunity to gorge himself. On the other hand, when corn or barley are cheaper than oats, these concentrates can be used with entirely satisfactory results. No matter what feed is given to horses, it must be of good quality because horses are especially susceptible to injury from damaged feeds.

## Composition of Feeds

The composition of the more common feeds used for feeding horses is presented in Table 6. The values are expressed in terms of those nutrients for which the recommended allowances are given in Tables 1, 2 and 3.

Individual values may vary widely from the indicated averages. The composition of feeds may vary with stages of maturity, variety, climate, soil, method of preservation and length of storage period.

The mineral composition of feeds is subject to considerable variation, depending on the amounts and availability of the various elements in the

TABLE 7
EXAMPLE RATIONS FOR HORSES

| Ration, Class and Weight of Horse | Feed | Digestible Protein | Total Digestible Nutrients | Calcium | Phosphorus |
|---|---|---|---|---|---|
| | *lb.* | *lb.* | *lb.* | *gm.* | *gm.* |
| Ration 1. Maintenance, 1200 lb. | | | | | |
| Oat or barley hay | 19 | 0.93 | 9.0 | 18.0 | 16.3 |
| Recommended | | 0.71 | 9.0 | 15.7 | 17.7 |
| Ration 2. Light work, 1800 lb. | | | | | |
| Timothy hay | 18 | 0.52 | 8.8 | 18.7 | 16.4 |
| *Corn | 9 | 0.59 | 7.2 | 0.8 | 11.0 |
| Total | | 1.11 | 16.0 | 19.5 | 27.4 |
| Recommended | | 1.19 | 15.8 | 21.1 | 23.8 |
| Ration 3. Medium work, 1200 lb. | | | | | |
| Timothy hay | 15 | 0.44 | 7.3 | 15.6 | 13.6 |
| Oats | 3 | 0.28 | 2.2 | 1.2 | 5.8 |
| Corn | 5 | 0.33 | 4.0 | 0.4 | 6.1 |
| Total | | 1.05 | 13.5 | 17.2 | 25.5 |
| Recommended | | 1.04 | 13.5 | 15.7 | 17.7 |
| Ration 4. Pregnant mare, 1200 lb. | | | | | |
| Alfalfa hay | 4 | 0.42 | 2.0 | 26.7 | 4.4 |
| Prairie hay | 9 | 0.19 | 4.5 | 14.7 | 7.4 |
| Oats | 8 | 0.75 | 5.8 | 3.3 | 15.6 |
| Total | | 1.36 | 12.3 | 44.7 | 27.4 |
| Recommended | | 1.04 | 12.2 | 17.7 | 17.7 |
| Ration 5. Lactating mare, 1200 lb. | | | | | |
| Timothy hay | 8 | 0.23 | 3.9 | 8.3 | 7.3 |
| Alfalfa hay | 7 | 0.74 | 3.5 | 46.7 | 7.6 |
| Oats | 10 | 0.94 | 7.2 | 4.1 | 19.5 |
| Corn | 7 | 0.46 | 5.6 | 0.6 | 8.5 |
| Total | | 2.37 | 20.2 | 59.7 | 42.9 |
| Recommended | | 2.30 | 20.0 | 28.0 | 25.4 |
| Ration 6. Growing colt, 600 lb. Mature wt. 1200 lb. | | | | | |
| Timothy hay | 6 | 0.17 | 2.9 | 6.2 | 5.5 |
| Alfalfa hay | 2 | 0.21 | 1.0 | 13.3 | 2.2 |
| Oats | 3 | 0.28 | 2.2 | 1.2 | 5.9 |
| Corn | 2 | 0.13 | 1.6 | 0.2 | 2.4 |
| Wheat bran | 1 | 0.13 | 0.7 | 0.6 | 5.9 |
| Total | | 0.92 | 8.4 | 21.5 | 21.9 |
| Recommended | | 0.93 | 8.3 | 16.9 | 16.3 |

* Grain may be corn, barley, oats or sorghum.

soil. There are geographical areas where phosphorus, or iodine, or calcium or other elements are deficient in the herbage. The carotene content of forage is subject to wide variations, depending on both the stage of maturity at harvesting and the length of storage. It decreases rapidly by oxidation, especially at high temperatures and exposure to sunlight. The best practical guide to the carotene content of forage and silage is the degree of green color.

## Examples of Adequate Rations

The sample rations in Table 7 are intended to illustrate the use of the data in Tables 1, 2, 3 and 5. Each ration shows the amount of nutrients in each feed used and the total furnished by the ration as compared with the recommended allowance. Some of the rations may provide more than the recommended amounts of certain nutrients. Where liberal amounts of legume hays are fed, the amounts of protein and calcium provided may be in excess of the amounts recommended. While the usual combinations of feeds may supply more of certain nutrients than recommended, there is no objection to such rations so long as they are the most economical for a particular locality.

Typical rations that adequately meet the recommended nutrient allowances will vary with the section of the country, depending on available local feeds. For example, in the western states alfalfa hay may be the only roughage fed, while in the middle west and east alfalfa is rarely fed to horses in appreciable amounts.

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