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THE NEW NRC: UPDATED REQUIREMENTS FOR PREGNANCY AND GROWTH

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Introduction and Brief History of *Nutrient Requirements of Horses*

The National Research Council (NRC) appointed a committee to revise the publication *Nutrient Requirements of Horses* in March of 2004. The committee consisted of 11 members from diverse geographical and educational backgrounds. When the publication is printed, it will represent the sixth revision under the current title. Prior to the first edition of *Nutrient Requirements of Horses*, the NRC produced a publication titled *Recommended Nutrient Allowances for Horses*. This book was published in 1949 and could be purchased for fifty cents. Many of the concepts used to predict nutrient requirements in past versions of *Nutrient Requirements of Horses* are also used in the sixth revised edition. However, the sixth revised edition of *Nutrient Requirements of Horses* will include some new approaches to estimating requirements and new combinations of methods used in previous publications. A variety of approaches have been used to estimate requirements in the sixth revised edition of *Nutrient Requirements of Horses*. Although it would have been preferable to use one system for estimating requirements for all nutrients, this was not possible due to a lack of information in some areas. Therefore, some requirements have been estimated using data derived solely in horses, whereas other estimates have incorporated information derived for other species.

The sixth revised edition of *Nutrient Requirements of Horses* will include nutrient requirements for maintenance, pregnancy, lactation, growth, and work (regular, imposed exercise). A Web-based computer program will be available to calculate requirements and compare dietary supply to the requirements for a number of nutrients. Nutrient requirements are expressed in amounts per day rather than nutrient concentrations/densities. The Web-based program will calculate nutrient densities if the user specifies a level of intake. In addition to the written explanation of the derivation of the requirements, there will be chapters on feeds and feed processing, feed additives, feeding management, feed analysis, unique aspects of equine nutrition (including discussion of the nutritional management of horses with special needs), and nutrition of donkeys and other equids.

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This paper reviews the methods used to develop the protein and energy requirements for pregnant mares and growing horses. As in past versions of *Nutrient Requirements of Horses*, protein requirements are expressed as crude protein. However, crude protein requirements are generally derived from estimates of digestible protein requirements and dietary protein digestibility. Energy requirements are expressed in units of digestible energy. Some requirements have been derived from studies that reported digestible energy intakes, whereas other requirements have been derived from estimates of recovered energy (tissue or milk) and/or measures of heat production.

The Pregnant Mare

The nutritional requirements of pregnant animals are difficult to study, and thus the nutritional requirements of pregnant mares have received little attention from researchers. There are several reasons the nutrient requirements of pregnant mares have not been extensively studied. Mares have a relatively long gestation period, so the appropriate experimental period is long. Conducting even short-term nutritional balance studies with mares can be challenging. Mares can use body tissue to meet the demands of fetal development, making it hard to observe the effects of marginal nutrient intakes. It is often difficult to ascertain whether foals are born with "normal" or "optimal" nutritional and health status. Furthermore, it may take several months or years to realize any impacts of maternal nutrition on the offspring, so data must be collected on foals for several years after birth. Given these challenges, it is not surprising that there are fewer studies dealing with nutrition of the pregnant mare compared to other classes of horses.

The nutrients needed by pregnant animals can be partitioned into the following categories: (1) nutrients needed by the dam to maintain her body; (2) nutrients needed by the dam to synthesize fetal tissue; (3) nutrients needed by the dam to synthesize the accessory tissues of conception (the placenta, enlargement of the uterus, enlargement of the mammary gland); (4) nutrients needed to maintain the newly synthesized tissues of the fetus, placenta, uterus, and mammary gland.

To accurately calculate the nutrient needs of pregnant mares, it would be necessary to know the rate of accumulation of fetal and accessory tissues, the efficiency of nutrient use for the synthesis of this tissue, and the maintenance costs of these tissues. Very little of this information was available for use in the sixth revised edition of *Nutrient Requirements of Horses*. As a result, the requirements suggested in the sixth revised edition are based on limited data from horses, assumptions from previous editions of *Nutrient Requirements of Horses*, and some data from other species.

Slaughter of pregnant females at various stages of gestation has produced estimates of the rates of fetal and placental tissue accretion in other species. Bell et al. (1995) reported on the accretion of energy and protein in the gravid uterus of dairy cows slaughtered between 190 and 270 d of gestation. Ji and coworkers (2005) measured the

weight and composition of the fetus, uterus, and mammary gland of gilts slaughtered at 0, 45, 60, 75, 90, 102 and 112 d of gestation. Similar studies have not been conducted in horses. Information from papers published by Meyer and Ahlswede (1976; 1978) was used as a basis for several of the recommended intakes for pregnant mares that were reported in the 1989 edition of *Nutrient Requirements of Horses*. Meyer and Ahlswede (1976; 1978) determined the composition of aborted fetuses or foals that died at birth. Gestational age of the fetuses ranged from 161 to 354 days. Most of the fetuses were produced by Thoroughbred or Warmblood-type mares. Platt (1978) also reported fetal weights of aborted Thoroughbred foals. More recently, in an experiment designed to investigate equine fetal cardiovascular function, Giussani and coworkers (2005) reported the weights of several aborted fetuses and prematurely delivered foals from Welsh pony mares that had been instrumented between 143 and 328 days of gestation. Ideally, data from normal fetuses should be used to develop curves for fetal tissue accretion. However, in the absence of data from normal horses, data from the studies of Meyer and Ahlswede (1978), Platt (1978), and Giussani et al. (2005) were used to develop an equation to predict fetal weight during gestation. Meyer and Ahlswede (1978) had previously suggested that weight of Thoroughbred fetuses during late gestation could be calculated using the equation:

$$\text{Fetal wt (kg)} = 0.00067(X^2) - 20.7; \text{ where } X = \text{days of gestation.}$$

Although this equation may be useful for Thoroughbreds, it cannot be applied to horses with larger or smaller body sizes. To produce an estimate that would apply to more types/breeds of horses, fetal weights reported by each of the studies cited above were converted to a percentage of expected birth weight. These fetal weights as a percentage of mature weight were then used to develop an equation that could be used to estimate fetal tissue accretion across all mature body weights. In the study by Meyer and Ahlswede (1978), the protein and lipid contents of fetal tissue were relatively constant during the last 5 months of gestation at 60% protein and 10% lipid on a dry matter basis. Mineral content of the fetal tissue was more variable. Meyer and Ahlswede (1978) reported that calcium content of the fetal tissue in the seventh month of gestation was 59.5 +/- 14.8 g/kg DM. In the tenth month of gestation the value was 75.6 +/- 11.9 g Ca/kg DM.

An estimate of the nutrient accretion in the fetus is the first step in calculating a daily requirement. The next step is to estimate the efficiency of incorporating absorbed nutrients into fetal tissue. The efficiency of incorporation varies by nutrient. For example, the efficiency of digestible energy use for fetal tissue has been suggested to be 60% (NRC, 1966), whereas the efficiency of digestible protein use for fetal tissue deposition has been estimated at 45% (NRC, 1973). The efficiency of use of absorbed minerals is usually considered to be 100%. Finally, for nutrients such as protein and minerals, dietary availability must be considered.

In addition to the nutrients needed to deposit new tissue associated with conception, nutrients must also be used to maintain the newly deposited tissue. For example, during the tenth month of gestation, the fetus requires nutrients for growth plus nutrients to meet the metabolic demands of the existing tissues. Researchers at the University of Cambridge have developed sophisticated instrumentation techniques to study fetal metabolism in utero. These techniques have produced estimates of oxygen utilization by the fetus and associated tissues (Fowden et al., 2000). Their data suggest that rate of oxygen utilization by the tissues of conception is approximately double the average rate of oxygen utilized by the horse at maintenance. Very few data are available to assess the maintenance requirements of fetal tissue for other nutrients.

Although the fetus comprises the largest portion of the tissue accumulated during gestation, the other tissues of conception must also be considered. Placental weight at foaling is correlated with foal birth weight (Oulton et al., 2004; Whitehead et al., 2004). In a study of Standardbreds, average birth weight was 53 kg and placental weight was 4.4 kg. No data could be found on the increase in tissue weight sustained by the uterus during pregnancy in mares, so studies with other species were reviewed. It was estimated that uterine tissue accretion was equal to, and paralleled, placental tissue accretion. Data reported in a textbook (Ginther, 1992) suggest that accumulation of uterine and placental tissues begins in mid-gestation. In swine, combined fetal and placental tissues reach more than 50% of final weight by mid-gestation (Ji et al., 2005). At 190 days of gestation in cows, the non-fetal tissues and fluids of conception have attained more than 40% of final weight, whereas the fetus has attained less than 25% of birth weight at the same time (Bell et al., 1995). Studies in cattle and swine also suggest that the accretion of placental and uterine tissues follows linear functions. Therefore, it was concluded that placental and uterine development begins prior to the last trimester in horses and that it follows a linear function. In the fourth edition of *Nutrient Requirements of Horses* (1978), requirement estimates were given for mares in early gestation and during the last 90 days of gestation. In the subsequent edition (1989) of the publication, estimates were given for early gestation and the ninth, tenth, and eleventh months of gestation. In the sixth edition, requirements will be estimated for pregnant mares at less than 5 months of gestation and then at 5, 6, 7, 8, 9, 10, and 11 months of gestation. The crude protein and digestible energy requirements for mares in late gestation in the sixth revised edition of *Nutrient Requirements of Horses* are similar to, or slightly higher than, previous estimates (NRC, 1989). Another addition to this version of *Nutrient Requirements of Horses* will be estimates of the expected body weight of pregnant mares during the fifth through eleventh months of gestation.

Growing Horses

The nutrient requirements of growing horses have been estimated from a variety of methods. In the 1966 version of *Nutrient Requirements of Horses*, the protein

requirement for gain was derived from studies with cattle. However, in the third and fourth editions (1973; 1978), protein requirements for gain were derived from estimates of the amount of protein deposited in each kilogram of gain using body composition data from horses. In 1989 the protein requirements of growing horses were calculated from feeding studies with growing horses. In addition, the recommended crude protein and lysine intakes were linked to the daily digestible energy intake of the horses (NRC, 1989). The crude protein and lysine requirements for weanlings were 50 and 2.1 g/Mcal DE/day, respectively (NRC, 1989). The requirements for yearlings were 45 g CP/Mcal DE/d and 1.9 g lysine/Mcal DE/day (NRC, 1989). Possibly as a result of the different methods used to calculate the crude protein requirement, some of the estimates in 1989 and 1978 were quite different. For example, the recommended crude protein intake for a 12-month-old yearling with an expected mature body weight of 500 kg was 760 g/d in 1978 compared to 851-956 g/d in 1989 (depending on rate of growth). In the sixth edition of *Nutrient Requirements of Horses*, the committee chose to calculate crude protein and lysine requirements in a manner similar to that used in 1978, and protein requirements were no longer calculated from energy intakes. The text of the sixth edition provides information on the digestible protein needs of growing horses as well as the crude protein requirements. The recommended daily amounts of crude protein and lysine in the sixth edition are somewhat lower than in the 1989 edition, partly because protein digestibility in common feeds used for growing horses was estimated to be higher than in previous editions.

In the third and fourth revised editions (1973; 1978) of *Nutrient Requirements of Horses*, the digestible energy required for a kilogram of gain was estimated using the following equation:

$$\text{Kcal DE/kg gain} = 3.8 + 12.3X - 6.6X^2;$$
where X = fraction of mature weight (NRC, 1978)

The source of the equation to derive the amount of energy needed for a kilogram of gain was not given, but it may have been extrapolated from a previous equation developed from data for beef cattle described in the second edition of the publication (NRC, 1966). In 1989, estimates of the digestible energy needed per kilogram of gain were derived from the summarization of feeding studies with horses (NRC, 1989). The amount of digestible energy required per kilogram of gain was estimated by the following equation:

$$\text{Mcal DE/kg gain} = 4.81 + 1.17X - 0.023X^2;$$
where X = age in months (1989)

In the previous editions of *Nutrient Requirements of Horses*, the daily digestible energy intake of growing horses was calculated by adding the requirement for gain to the requirement for maintenance. In 1978, the digestible energy required for maintenance was calculated using the following equation:

Kcal DE/day = 155 $W^{0.75}$; where W = body weight in kilograms (NRC, 1978)

In 1989, the NRC committee abandoned the concept of expressing energy requirements on a metabolic body size and used an equation developed by Pagan and Hintz (1986) to estimate the digestible energy requirement for maintenance. The equation used in the 1989 NRC to estimate the digestible energy requirement for maintenance was:

Mcal DE/d = 1.4 + 0.03W; where W = weight in kilograms

When the equations for estimating the digestible energy needed for maintenance and gain were combined, the daily digestible energy intakes of horses were calculated in the 1989 NRC using the following equation:

Mcal DE/d = (1.4 + 0.03W) + (4.81 + 1.17X - 0.023X2)(ADG);
where W = weight in kg; X = months of age; and ADG = daily gain in kg

A comparison of predicted and actual weight gains of growing horses fed at or near NRC (1989) recommended digestible energy levels suggests that the equation developed in 1989 may have slightly overestimated the amount of digestible energy needed for the specified rates of gain (Lawrence, 2000). In the sixth revised edition of *Nutrient Requirements of Horses*, the committee considered whether the equation developed in 1989 to estimate energy requirements of growing horses should be modified. An important consideration was the method of determining the maintenance requirements of growing horses.

In 1978 and 1989, the NRC committee concluded that the equations for calculating maintenance requirements should apply to both adult animals and growing animals. Therefore, the amount of energy needed to maintain the body weight (no growth) of a 200-kg weanling Thoroughbred would be the same as the amount of energy needed to maintain the weight (no gain) of a 200-kg 10-year-old pony. Given the probable differences in body composition and potential differences in voluntary activity between an adult pony and a Thoroughbred weanling, it seems likely that maintenance requirements would also be different. In addition, when the 1989 NRC equation and assumptions about the composition of gain (NRC, 1978) are used to calculate the partial efficiency of digestible energy use for gain, the resulting value is relatively low, especially for horses 12 months of age and older. These considerations caused the committee to consider whether the equations developed in 1978 and 1989 correctly partitioned the energy for maintenance and the energy for gain in growing horses.

Limited data are available on the maintenance requirements of growing horses. Cymbaluk et al. (1989) determined mean maintenance values for growing horses (6 to 24 months of age) of 37.8 and 35.6 kcal/kg BW depending on the amount of diet that was fed. The horses in that experiment were turned out for 6 hours per day during the study. These data would suggest that the maintenance requirements of 15-month-old horses (average age during the study) would be approximately 36.5 kcal/kg BW. The

1989 NRC maintenance equation predicts a slightly lower digestible energy intake of 34 kcal/kg BW for a 350-kg yearling. Therefore, the maintenance equation suggested by Pagan and Hintz (1986) and later adopted by the NRC (1989) appears to slightly underestimate the maintenance needs of yearling horses. The discrepancy between actual and predicted maintenance requirements might be greater for younger horses. In one study of neonatal foals, the digestible energy for maintenance was close to 70 kcal/kg BW (Ousey et al., 1997). Coenen (2000) suggested that the maintenance requirement for 3- to 6-month-old horses was 210 kcal/W0.75, which would be approximately 55 kcal/kg BW. For the sixth revised edition of *Nutrient Requirements of Horses*, the available data on maintenance requirements of growing horses were summarized and an equation was derived to predict maintenance energy as a function of body weight and age. Several studies reporting age, body weight, digestible energy intake, and weight gain of growing horses were then used to calculate the digestible energy needed above maintenance for gain as a function of age. A new equation that combines the maintenance component and the gain component of the digestible energy intake was developed. This equation is similar in concept to the equation developed in 1989, but differs in that it tends to partition more energy towards maintenance and less energy towards gain.

The final step in calculating the energy needs of growing horses is to estimate average daily gain. The total amount of digestible energy required each day will vary with rate of gain. The committee appointed to revise *Nutrient Requirements of Horses* in March of 2004 received several requests to include growth curves for a variety of horse breeds in the publication. In previous editions of the publication, nutrient requirements and growth data were categorized by expected mature weight, not breed. Growth curves were shown in a figure in the 1978 edition of *Nutrient Requirements of Horses*, but no source for the information was cited and specific breeds were not identified. The sixth revised edition of *Nutrient Requirements of Horses* will not include breed-specific growth curves. The absence of breed-specific growth curves is partly due to an absence of data for many breeds. In addition, within some breeds there is a great deal of variation among horses. For example, a growth curve derived using halter-type Quarter Horses might not apply very well to cutting-bred Quarter Horses, even though they are members of the same breed.

The 1989 *Nutrient Requirements of Horses* provided estimates of body weights and average daily gains for horses at 4, 6, 12, 18, and 24 months of age. The source of the data used to develop these estimates was not given, and there were some inconsistencies between the body weight estimates and the average daily gain estimates. The body weight of a weanling expected to mature at 500 kg was predicted to be 175 kg at 4 months and 215 kg at 6 months (NRC, 1989). Based on these two weights, the expected average daily gain would have been 0.66 kg/d (40 kg in 60 days). However, the suggested rates of daily gain were 0.85 kg/d for the 4-month-old, and 0.65 to 0.85 kg/d for the 6-month-old horses. A goal of the committee appointed to revise *Nutrient Requirements of Horses* was to develop a method to predict the growth rate of all types of horses. The method that was developed can be applied across breeds

to calculate weight at a specific age. Once body weight is estimated, average daily gain can be calculated.

A number of researchers have studied growth characteristics of Thoroughbred horses including Green (1969), Hintz et al. (1979), Jelan et al. (1996), Pagan et al. (1996), and Kavazis and Ott (2003). Fewer or less comprehensive studies are available for other breeds. Therefore, to obtain a continuous growth curve that would apply to all horses, the committee to revise *Nutrient Requirements of Horses* took an approach of expressing growth as a function of mature weight. This is not a new concept and has been described by others including Austbo (2004) and Coenen (2000). To obtain an equation to predict body weight at any age from mature weight, growth data from the following breeds or types of horses were summarized: Thoroughbred, Morgan, Quarter Horse, pony, Arabian, Belgian, Hanoverian, and Swedish Standardbred. Once data for each breed were summarized by age, body weights were expressed as a percentage of mature body weight. Mature body weights were obtained from values given in the reviewed papers or from a search of the literature. The data from all breeds/types were combined, and a single growth curve was developed. The resulting growth curve can be applied to any breed or type of horse, if an estimate of expected mature weight is available. There were insufficient data to generate separate curves for colts, fillies, and geldings. However, different estimates of body weight at any age will be obtained if users estimate different mature weights for stallions, geldings, and mares. There were also insufficient data to generate separate curves for ponies, light horses, and draft horses. Although representatives of each type of horse were included in the data used to generate the final equation, the data set for Belgian horses included only foals/weanlings.

The committee recognizes that there are some limitations to the method developed to predict equine growth in the sixth revised edition of *Nutrient Requirements of Horses*. First, the method that was developed was based on body weight data and did not incorporate any factor for optimal skeletal growth. The committee did not find sufficient data to quantify an optimal growth rate. Therefore, the method that was developed provides information only about the average rate of gain and does not account for growth rates that might be preferred in order to meet specific production goals of an individual horse owner. Second, the equation developed to predict body weight suggests that rate of gain continuously decreases with age, a situation which may not occur in practice. Real-world data sets suggest that average daily gain varies with environment and that the rate of gain of yearlings on high-quality pasture in the spring may exceed the rate of gain of weanlings/yearlings during the prior winter (Pagan et al., 1996; Asai, 2000; Staniar et al., 2004). Therefore the method suggested in the sixth revised edition of *Nutrient Requirements of Horses* probably overestimates average daily gain of weanlings/yearlings in the winter and underestimates their growth rate the following spring. Finally, the method to estimate growth rate in the sixth revised edition of *Nutrient Requirements of Horses* was developed primarily with data from horses with mature body weights of 400 to 600 kg. Therefore it is not known how well this method will apply to miniature horses, small ponies, or draft

horses. Examination of body weights listed in the fifth revised edition of the NRC (1989) suggested that previous committees expected small breeds to mature more rapidly than large breeds. For example, 12-month-old ponies (200 kg mature weight) had a suggested body weight of 140 kg (70% of mature weight). However, draft horses with an expected mature weight of 900 kg had a suggested weight of 500 kg (55% of mature weight) at 12 months of age (NRC, 1989). As noted previously, the source of the data used to derive the body weights in the 1989 publication was not given. It is hoped that future research projects will focus on characterizing growth in more breeds and types of horses that are raised in commercial environments so that better guidelines for optimal growth rates can be developed.

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