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J.D. Pagan

MACROMINERALS - CALCIUM, PHOSPHORUS AND MAGNESIUM

HAROLD F. HINTZ
Cornell University, Ithaca, NY

The 1989 National Research Council (NRC) requirements for calcium, phosphorus and magnesium are the latest published guidelines for equine ration formulation. Since that time, research has led nutritionists to suggest changes in requirements.

Calcium

The calcium requirements were estimated for the 1989 NRC publication by the factorial method. The maintenance requirement was estimated and then estimates were added for the amount of calcium needed for fetal growth, milk production or growth of foal to provide requirements for pregnant mares, lactating mares and growing animals, respectively.

Maintenance

Estimates for maintenance requirements were, for the most part, based on measurements of endogenous losses in feces and urine. The losses were measured with the use of isotopes or by extrapolation from studies in which Ca balances were determined in animals fed a wide range of Ca intake. In the latter case, the endogenous loss was estimated by extrapolating the loss of Ca at zero Ca intake. The amount of dietary Ca needed to replace endogenous losses was calculated by assuming the efficiency of absorption was 50%. There are several potential sources of error in such an approach. The length of the balance studies was seldom greater than ten days. It is quite probable a horse can adapt to a lower level of calcium when fed over long periods.

The validity of the estimate of 50% efficiency of absorption is of concern. Many factors such as Ca:P ratio, form of Ca, level of Ca intake and presence of inhibitors such as phytate and oxalate can influence the efficiency of absorption.

For example as the dietary intake of Ca decreases, efficiency of absorption may increase. Absorptive rates of 70% or greater are often found when a readily available source of Ca was fed at near maintenance levels.

The 1989 NRC maintenance requirement for a 500 kg horse is 20 g of calcium. Pagan (1994) reported endogenous losses for Ca that were higher than estimated by NRC but he also found higher true digestibility. Therefore, the two factors combined resulted in maintenance requirements similar to those suggested by NRC.

It was thought that the estimates of the Ca maintenance requirement made by the factorial method were probably on the liberal side because of the potential adaptations that could be made by the horse over a long period. It was also thought that liberal estimates were better than conservative estimates, thereby decreasing the chance for the horse to suffer from Ca deficiency. The horse can easily adapt to moderate Ca excesses by limiting absorption and increasing urinary excretion.

A direct approach in which bone was actually evaluated would be preferred to the indirect approach used above. For example, it would be desirable to feed horses various levels of Ca for prolonged periods and measure bone mineralization over those periods to determine if bone integrity is maintained.

I found no studies that suggested horses at maintenance fed Ca intakes satisfying the 1989 recommendations were at risk of being Ca deficient, at least in cases where no inhibitors such as excess P, phytate and/or oxalate were present in the feed.

The increased use of commercial feeds over the last several decades has significantly decreased the incidence of Ca deficiencies. However, the potential for Ca deficiency cannot be ignored. Many case reports have demonstrated that severe Ca deficiency, hypocalcemia or nutritional secondary hyperparathyroidism still exist worldwide because of inadequate feeding practices (Richardson et al., 1991; David et al., 1997; Hintz, 1997a; Ramirez and Seahorn, 1997; Couetil et al., 1998; Hudson et al., 1999; Wisniewski et al., 1999).

It is frustrating that the importance of dietary Ca is still not understood by all those who care for horses, particularly when Ca supplements can usually be purchased inexpensively. The lack of attention to the Ca content of the diet has caused many horses to suffer, even in modern times.

Pregnant Mares

Calcium deposition in the fetus was estimated to be 11.1, 25.3 and 11.4 grams of calcium daily per kg of the mare's body weight during months 9, 10 and 11 of gestation, respectively (Meyer and Ahlswede, 1976; Drepper et al., 1982). The NRC decided to use a mean daily deposition rate of 15.9 mg of calcium/kg of mare body weight during the last three months. Again, as for maintenance, it was assumed the efficiency of absorption was 50%. The mean dietary calcium required for deposition was added to maintenance needs and divided by the mean digestible energy (DE) requirement for the same period. This value was then multiplied by the daily DE requirement for each month. The daily requirements for various weights of mares are shown in Table 1.

Table 1. Estimates of daily calcium requirements for pregnant mares (NRC).

Body Weight	Month of Gestation		
kg	9	10	11
400	28	29	31
500	35	35	37
600	41	42	44
700	45	46	49
800	48	49	52
900	51	52	55

The 1989 NRC estimates were slightly greater than those of 1978 and much greater than the estimates of 1949, 1961 and 1973 (Table 2). If the grain contained 3.3 Mcal/kg and hay contained 2 Mcal/kg of dry matter, it could be calculated that the diet should contain 0.45% calcium compared to 0.22% calcium recommended in 1949.

Table 2. Changes in estimates of daily calcium requirements by NRC[a].

Year	Edition	g/day
1949	1	16.5
1961	2	17
1973	3	24
1978	4	34
1989	5	35-37

[a]500 kg pregnant mare in late gestation.

Estimates by the French and German counterparts of NRC are similar to those of NRC (Table 3). Perhaps the similarity should be expected because the NRC committee used data from those countries when making its estimates, and the French and German committees used data from the United States. However, it is encouraging that three scientific committees arrived at similar results after independently studying the data that are available.

Table 3. Estimates of calcium requirements of mares in late pregnancy[a].

Source	g/day
NRC (1989)	35-37
Meyer (1994)	38
Martin-Rosset (1990)	38-39

[a]500 kg mare

Martin et al. (1996) studied calcium metabolism by a different method than balance studies. They measured changes in serum concentrations of calcium and parathyroid hormones in mares fed diets containing calcium concentrations below (0.35%) and above (0.55%) the NRC requirement of 0.45%. They concluded, "The practical importance of dietary calcium for mares during the last month of pregnancy has been reinforced by our findings." They found less extreme perturbations of serum total calcium, ionized calcium and parathyroid hormone in the mares that were fed 0.55% calcium than in mares fed 0.35% calcium. They suggested that the optimal concentration of dietary calcium for prepartum mares was closer to 0.55% than 0.35%.

Glade (1993) estimated metacarpal breaking strength (MBS) by transmission ultrasonics of mares during the last 12 weeks of gestation and for 40 weeks after parturition. MBS increased during the last 6-10 weeks of gestation in mares fed amounts of Ca similar to NRC recommendations but mares fed 20% less Ca than NRC recommendations did not have an increase in MBS. Furthermore, foals of the mares fed the lower level of Ca had thinner mid-cannon mediolateral diameters and mechanically weaker bones at birth than foals of control mares and the differences persisted for 40 weeks.

The studies by Martin et al. (1996) and Glade (1993) indicate that the pregnant mare probably needs a Ca intake at least as great as NRC recommendation but extrapolations as to the optimum level of Ca from their data are not possible because only two concentrations were used in each of the studies.

Lactating Mares

It was estimated that the milk of mares contains about 1.2 g of Ca per kg of fluid milk during early lactation (foaling to three months) and 0.8 g of Ca per kg of fluid milk during late lactation (three months to weaning) (Schryver et al., 1986). Similar data were recently reported by Grace et al. (1999a). NRC (1989) assumed the mare produced milk at a rate of 3% of body weight in early lactation and 2% in late lactation. Again, an absorption rate of 50% was assumed. The calcium requirements for a 500 kg mare would be 56 g of calcium/day in early lactation and 36 g of calcium/day in late lactation. NRC calculated that the typical diet of the mare should contain 0.47% and 0.33% Ca during early and late lactation respectively.

Glade (1993) reported that mares fed the NRC recommended levels of Ca gradually lost density during the first 12 weeks of lactation, but bone density started increasing at that time and was fully restored at 24 weeks post-parturition. However, mares fed 20% less Ca than recommended had not recovered bone density at 40 weeks after parturition even though the foals were weaned at 20 weeks.

Growing Horses

NRC assumed that the growing horse required about 16 g of Ca/kg of gain. A foal weighing 215 kg with an estimated mature weight of 500 kg and gaining 0.65 kg per day would require 29 g of Ca/day. A foal gaining 0.85 kg/day would need 34 g of Ca/day.

Grace et al. (1999b) measured the body mineral content of 21 foals at about 150 days of age. The foals had grazed on tall fescue pasture. The body levels of calcium, phosphorus and magnesium were similar to values previously reported by Schryver et al. (1974) and utilized by NRC in 1989.

Grace et al. (1999b) calculated that a 200 kg horse gaining 1.0 kg/day would require 28 g of calcium per day. The NRC estimate for the same weight of foal and rate of gain is 30 g of calcium per day. The estimate by Grace et al. (1999b) was lower than NRC values because they estimated the coefficient of absorption to be 70% compared to the 50% used by NRC.

It has been suggested that dietary cation-anion difference (DCAD) could influence calcium utilization and perhaps lead to a calcium deficiency in growing horses (Wall et al., 1997). However, Cooper et al. (2000) recently reported that horses consuming a lower DCAD can compensate for the increased urinary excretion of calcium by enhancing intestinal calcium absorption and thereby maintain calcium status. Young horses fed about 30 g of calcium per day were in positive balance and had no obvious calcium problems when fed high or low DCAD diets.

Young Horses In Training

NRC recommendation for young horses in training was based on extrapolations and the assumption that if the Ca:calorie ratio was maintained the increased feed intake needed to supply the extra energy for work would also supply the calcium needed for bone formation and for that lost in sweat (Hintz, 1997b).

Nielsen et al. (1997a) studied changes in the third metacarpal bone in Quarter Horses put into race training at 18 months of age. Bone density began to decrease at the onset of training and continued to do so until day 62 of training, remaining low through day 104 when it began to increase to day 244. Horses with greater cortical mass in the lateral and medial aspects of the third metacarpal relative to the palmar aspect at the commencement of training had fewer injuries. Could additional calcium help delay the loss of bone density?

Nielsen et al. (1997b) studied calcium balance in Quarter Horses about two years of age. Sixteen horses were started in race training. The trial was blocked into four periods of 28 days. The horses were galloped 5500 m on a track for the first week and 8250 m per week for the last three weeks of the period. During the third period, the horses galloped 4630 m per week and did a weekly sprint of 230 m. During the fourth period, the horses were galloped for 4585 m and sprinted for 275 m per week.

Balance studies were conducted for three days every 28 days. Eight horses were fed about 36 g of Ca per day during the last three periods and eight horses were fed about 30 g of Ca per day. The horses fed the higher Ca intake retained 4-6 more grams of Ca per day during the balance periods than the horses fed the lower intake. This study demonstrated that Quarter Horses, about 24 months of age and weighing around 485 kg, in typical race training required at least 36 g of calcium daily. This is slightly above the NRC estimate of 34 g per day. Nielsen et al. (1997b) recommended that diets for young horses in training should contain 0.4% calcium and that seems to be a prudent recommendation.

Phosphorus

Maintenance

The endogenous losses of phosphorus were estimated at 10 mg/kg of body weight and an absorptive efficiency of 35% was used because maintenance diets are likely to contain plant sources of phosphorus (NRC, 1989). Factors influencing phosphorus absorption include form of phosphorus. Phytate phosphorus, the type often found in grains, was considered not to be as effectively utilized as inorganic phosphorus. The maintenance requirement of phosphorus of a 500 kg horse was estimated to be 14 g.

Pagan (1994) reported endogenous phosphorus losses slightly lower than NRC but he also reported lower true phosphorus availability. Therefore, the two factors combined for a daily phosphorus requirement similar to that of NRC.

The same potential problems suggested for the calcium requirements determined by the above method exist for phosphorus. Cymbaluk and Christison (1989) suggested that young horses could adapt to lower dietary phosphorus intake. Increased intake of phosphorus does not greatly decrease phosphorus utilization (Schryver et al., 1974), but environment might influence phosphorus utilization. Cymbaluk et al. (1990) reported that the true digestibility of phosphorus was greater in horses housed in a warm barn (mean temperature of 10.9 + 0.66°C) than in a cold barn (mean temperature of -5.2 + 1.72°C).

Age of the horse might also influence digestibility of phosphorus. Horses eight months of age were more efficient than horses 12 months of age (Cymbaluk et al., 1990).

Pregnant Mares

The phosphorus deposition in the fetus was estimated to be 9.4 g/day for a 500 kg mare during the last three months of gestation based on the body composition data of Drepper et al. (1992). An efficiency of absorption of 35% was assumed. Thus, a 500 kg mare would require about 27 g of phosphorus per day.

Lactating Mares

The phosphorus content of fluid milk in early lactation was 0.75 g/kg and decreased to 0.50 g/kg during late lactation (NRC, 1989). Similar values were reported by Grace et al. (1999a). An absorptive efficiency of 45% was assumed because a significant amount of the phosphorus in a ration for a lactating mare would probably come from inorganic sources, which perhaps would be used more effectively than plant sources of phosphorus.

Growing Horses

NRC (1989) suggested that growing horses with an expected mature weight of 500 kg would need 16 to 20 g of phosphorus per day. Grace et al. (1999b) suggested 21 g of phosphorus per day. Cooper et al. (2000) reported that horses about six months of age fed 17 g of phosphorus were in positive phosphorus balance and no bone problems were reported.

Magnesium

Maintenance

There are fewer measures of endogenous losses of magnesium and true digestibility of magnesium available than for calcium and phosphorus. NRC used a value of 6 mg/kg of body weight. Meyer and Ahlswede (1977) suggested a value of 7 mg/kg of body weight whereas Pagan (1994) reported 2.2 mg/kg of body weight. Hintz and Schryver (1972) reported true digestibility values of 40-60%.

Pagan (1994) reported an average of 52%. Thus the data of Pagan would indicate a requirement of 4 g/day for a 500 kg horse whereas NRC suggested 7.5 g/day and Meyer recommended 10 g/day. Further studies are needed to better define the magnesium requirements. However, there is no evidence that the 1989 recommendations are not adequate and the data of Pagan (1994) suggest they can be decreased.

Pregnant Mares

As with calcium and phosphorus, body composition data from the laboratory of Dr. Helmut Meyer (Drepper et al., 1982) were utilized to estimate requirements of mares. Deposition of magnesium was calculated to be 0.3 mg/kg of body weight of the mare and it was calculated a 500 kg mare would need about 9 mg of magnesium per day.

Lactating Mares

It was estimated that the magnesium concentration of milk averages 90 mg/kg during early lactation and 45 mg/kg during late lactation. Thus, a 500 kg mare would need about 11 g of magnesium during early lactation and 8.5 during late lactation.

Growing Horses

NRC estimated that growing horses with an expected mature weight of 500 kg would need about 4 g/day. Grace et al. (1999b) suggested 4.4 mg/day.

Discussion

Nutrient requirements of the macrominerals have apparently not received a great amount of attention in the last decade. Only the calcium requirements of the pregnant mare and of the young horse in training were questioned in the papers that were reviewed. Emphasis on the mineral needs of the performance horse is justified. Musculoskeletal injuries continue to be of major concern. Estberg et al. (1996) reported that 1.7/1000 California Thoroughbred race entrants were euthanized because of catastrophic musculoskeletal injuries. Bailey et al. (1998) reported a rate of 0.6 musculoskeletal injuries per 1000 entrants in flat races and 14/1000 entrants in steeplechases. More (1999) reported a high wastage of Thoroughbreds in Australia. Only 46% of the horses started at 2 or 3 years raced for two years after their first start. Removal from racing was linked to poor performance. The role of musculoskeletal problems in the poor performance remains to be determined.

Many factors such as accumulation of a large total of high-speed distances or rapid accumulation of high speed distances within a two-month period may increase the risk of musculoskeletal injuries (Estberg et al., 1996). Firth et al. (1999) suggested that imaging techniques could be developed to monitor bone changes and thus allow appropriate changes in training intensity to minimize damage. The effect of nutrition on bone changes such as bone density, bone stiffening and shock absorbing capability should receive greater attention using the new methods of bone evaluation.

However, answers about the role of nutrition will not come easily. Porr et al. (1998) reported that stall rest for 12 weeks decreased the bone mineral content of highly conditioned mature Arabian horses. Loss of BMC was not prevented by dietary calcium intake at twice the level recommended by NRC. In conclusion, I agree with Grace et al. (1999b) who stated that dietary requirements of minerals "need to be reviewed as new data come to hand because there is a dearth of information on the endogenous losses and coefficients of mineral elements." However, I think more studies using direct methods to measure the effect of mineral intake on bone integrity are required.

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