MINERAL REQUIREMENTS IN THE HORSE: A HISTORICAL PERSPECTIVE

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Equine mineral nutrition has long been of great interest to me. In fact, I have been fascinated by mineral nutrition of the horse ever since my days as a graduate student at Cornell University where I observed the animals in the studies of Krook and Lowe (1964). It was demonstrated that an imbalance of calcium and phosphorus could cause lameness in growing horses within 12 weeks after being fed the imbalanced diet. The lameness was described as being "insidious shifting." Because the entire skeleton was affected, the lameness shifted from one leg to another . When the horse favored the lame leg, the other three became more stressed. Inevitably, one of the three would then show signs of lameness. The horses also demonstrated a rabbit hopping gait, which I assumed was to decrease stress on the hind legs. Repletion with calcium was effective in treating the lameness.

Of course, calcium deficiency had been demonstrated in horses long before the studies of Krook and Lowe. Many case histories of "big head disease," or osteoporosis, can be found in the horse and veterinary literature of the 1800's and early 1900's (Hornbrook, 1826 and James, 1886). Berns (1890) reported that hundreds of horses were lost annually in New York City to osteoporosis. The disease was named "big head" because of the increase in head size. When horses are fed a diet lacking in calcium, the concentration of blood calcium drops which is a trigger to release parathyroid hormone. This hormone releases calcium from the bone in an attempt to maintain the needed concentration of blood calcium. The blood level of calcium needs to remain within certain limits because calcium is necessary to maintain normal nervous and muscle tissue activity. In the horse, when extensive calcium is removed from the head, the fibrous connective tissue content increases and the head actually increases in size, the head appears puffed or swollen, hence the name "big head disease."

Many theories ranging from poor ventilation (Berns, 1890) to infectious disease (Jasme, 1891) were proposed as to the etiology of "big head." Many severe treatments such as burning the enlarged area with a hot iron (Hornbrook, 1826), puncturing the enlarged area with an awl and pouring arsenic into the opening were used without success (Stowell, 1858). In the late 1800's limestone and other calcium supplements were found to be beneficial (Marshall, 1899). The incidence of the disease gradually decreased but information was not spread as rapidly then as it is now, hence, the calcium treatment was not immediately accepted. Even as late as 1901, the famous

Cornell veterinarian James Law wrote “Faulty food - a lack of lime - has been a favorite explanation ... but there is a growing tendency to suspect a microbial origin.” Although the severe cases of calcium deficiency that result in big head are not common today, the condition still appears from time to time. We also believe marginal cases of calcium deficiency resulting in predisposition of lameness are not a rarity.

In 1967 the Equine Nutrition Program was formed at Cornell University, thanks largely to the efforts of Dr. Steve Roberts of the College of Veterinary Medicine. The program was a joint effort between the College of Veterinary Medicine and the College of Agriculture and Life Sciences. Dr. Herbert Schryver and I were first to be hired with Dr. Jack Lowe soon joining the team. Our first goal was to study the effect of nutrition on the skeleton of the horse. We decided that the first step to reach the goal was to learn more about basic mineral metabolism of the horse. Because of the obvious relationship of calcium to the skeleton, the decision was made to study calcium nutrition.

First we studied the maintenance requirements (Schryver *et al*., 1970, and Hintz *et al*., 1973). Several methods can be used to estimate maintenance requirements. One approach is the balance study. Calcium intakes above and below the estimated requirement are fed to mature animals in metabolism stalls. Calcium intake, fecal and urinary calcium losses are determined. Intake is plotted against retention. The intake of calcium needed for zero calcium retention (maintenance) can then be calculated. Another approach is to measure obligatory (endogenous) losses in urine and feces. Endogenous losses are those that the body loses regardless of intake and can be measured with isotope studies or with balance studies in which losses are extrapolated at zero nutrient intake. Knowledge of endogenous losses is useful not only in the estimation of maintenance requirements, but also for the factorial method to measure requirements above maintenance. Endogenous losses are also needed to determine true digestibility of nutrients. For example, if the endogenous fecal loss of calcium is 2 g/100 kg of body weight, a 500 kg horse would excrete 10 g of endogenous calcium in the feces daily, even when the diet provided no calcium. If calcium was fed at a rate of 20 g per day and 20 g of calcium appeared in the feces, the apparent digestibility would be zero. However, if the fecal loss is corrected for endogenous loss (20-10=10), the true digestibility would be 50% (10 g in feces ÷ 20 g of intake). True digestibility is particularly valuable when comparing sources of calcium or when studying the effect of level of calcium intake on calcium metabolism.

Our estimates of maintenance requirements obtained by the balance study method and by the use of endogenous losses were similar. We calculated that horses lost 20 to 25 mg of endogenous calcium/kg of body weight/day. The calcium in a typical ration had an efficiency of absorption of around 50 percent in mature animals fed at a reasonable rate. Thus the horse would need 40 to 50 mg of dietary calcium/kg of body weight/day.

If the calcium intake was excessive, the efficiency of absorption was decreased (Schryver *et al*., 1970). Ca:P ratio, oxalate and source of calcium could also influence efficiency (Whitlock *et al*., 1970, Schryver *et al*., 1971a, Hintz *et al*., 1972, Swartzmann *et al*., 1978, and Hintz *et al*., 1984). Nevertheless, it seemed reasonable to estimate that horses weighing 500 to 600 kg needed about 20-24 grams of calcium per day for maintenance. Pagan (1994) recently reported similar values from his balance studies. Our estimates for maintenance were used in the 1973, 1978 and 1989 NRC publications of Nutrient Requirements of the Horse. Similar values were used in the 1982 and 1994 German standards (Meyer *et al*., 1994) and the 1990 French standards (INRA. 1990).

Calcium requirements of pregnant mares were calculated by adding the amount deposited in the fetus during late gestation, with an assumed efficiency of 50%. The values for the mineral content of new born were obtained from body composition studies conducted in Germany. We estimated that a 500 kg mare would need 35-37 grams of calcium daily during late gestation. The German estimate was 38 g per day, the French estimate was 39 g per day.

Calcium requirements of the lactating mare were calculated by adding the amount of calcium in milk to the maintenance requirement, again corrected for efficiency of utilization. Milk production and milk composition were estimated in several studies including those at Cornell University (Schryver *et al*., 1986). The estimates of milk composition are probably more accurate that the ones for milk production. Our estimates of calcium needs are 50 to 56 g per day for a 500 kg mare in early lactation and 36 to 41 g per day for a mare in late lactation. German estimates are 52 g per day for early lactation and the French estimates are 47-61 g per day.

We estimated calcium requirements for growing horses by adding the amount of calcium deposited in body gain corrected for efficiency of utilization to the maintenance requirement (Schryver *et al*., 1974). Horses 4 to 12 months of age with an expected mature weight of 500 kg would need 29 to 36 g of calcium per day. German estimates are 20 to 33 g per day, French estimates are 28 to 39 g. However, the optimal composition for bone has not yet been determined and more studies on the effect of calcium intake on bone integrity in the horse should be conducted.

Phosphorus requirements were estimated by the same methods used to estimate calcium (Schryver *et al*., 1971b). The values were 15-18 g per day for 500-600 kg horses. Pagan (1994) reported values of 18.5 g per day. German and French values are 15 g per day. Our values for pregnant mares (23 - 28 g daily) are similar to the French and German estimates. Mares in early lactation need 34 to 36 g per day. German estimates are 35 g, French estimates are 40 to 55 g. We suggest that growing horses need 16 to 20 g of phosphorus daily while French values are 16 to 22 g and German values, 18 to 23 g per day.

There has been considerable discussion concerning the copper requirements of growing horses since Knight and co-workers (1985) reported a negative correlation between the copper concentrations in the diets for weanlings and incidence of skeletal problems. These findings resulted from a survey of horse farms. They suggested that the copper requirement might be 30 to 50 mg/kg of diet. There is no doubt that copper deficiency can induce skeletal problems. Osteochondrosis has been produced experimentally in foals fed a diet containing 1.7 mg of copper per kg of feed (Bridges and Harris. 1988). Hutrig *et al* (1993) fed 18 foals diets containing 8 or 25 ppm copper. They concluded there was a relationship between low copper intake in fast growing horses and inferior collagen quality, biomechanically weak cartilage and osteochondrosis lesions. All nine foals fed the low copper diet had histological lesions but only 5 developed clinical lesions. It was concluded that factors other than nutrition, such as individual variation in growth or genetic potential, influence the expression of osteochondrosis.

We estimated copper and zinc maintenance requirements with balance studies (Cymbaluk *et al*. 1981). We found it difficult to measure endogenous zinc losses with isotope studies. Our studies with copper indicate the maintenance requirement may be slightly less that the 10 ppm suggested by NRC. In 1989, NRC considered that the studies which Knight et al used to suggest the necessity for high levels of copper to be inconclusive and decided not to increase their estimates of requirement but to keep it at the concentration of 10 mg/kg of diet. Meyer (1994) recently suggested a requirement of 10-12 mg per kg of diet but he also pointed out that attention should be paid to copper status of weaned foals that graze pastures that contain low copper concentrations. In our studies, the factorial method using body composition to estimate copper requirements in growing horses failed to provide data to suggest a diet containing 10 ppm copper to be inadequate for growing horses.

References

Berns, G.H. 1898. Osteoporosis. J. Comp. Med. Surg. 19:651-654.

Bridges, C.H. and E.D. Harris. 1988. Cartilaginous fractures (“osteochondritis dissecans”) induced experimentally in foals with low copper diets. J. Am. Vet. Med. Assoc. 193, 215-221.

Cymbaluk, N.F., H.F. Schryver and H.F. Hintz. 1981. Copper metabolism in mature ponies. J. Nutr. 111:87.

Hintz, H.F. and H.F. Schryver. 1972. Magnesium metabolism in the horse. J. Anim. Sci. 35:755.

Hintz, H.F. and H.F. Schryver. 1973. Magnesium, calcium and phosphorus metabolism in ponies fed varying levels of magnesium. J. Anim. Sci. 37:927.

Hintz, H.F., H.F. Schryver, J. Doty, C. Lakin and R.A. Zimmerman. 1984. Oxalic acid content of alfalfa hays and its influence on the availability of calcium, phosphorus, and magnesium to ponies. J. Anim. Sci. 58:939.

Hornbrook, S. 1826. Big head. New England Farmer. 5:150-151.

Hutrig, M., S. Green, H. Dobson, Y. Mikuni-Takagaki and J. Choi. 1993. Correlative study of defective cartilage and bone growth in foals fed a low-copper diet. Equine Vet. J., Supplement 16. 66-73.

INRA. 1990. L’alimentation des chevaux. W. Martin-Rosset, ed. Paris. 277.

James, H.F. 1886. Osteo-porosis. J. Comp. Med. Surg. 7:293-196.

Jasme, A. 1891. Osteo-porosis. J. Comp. Med. Surg. 12:404-407.

Knight, D.A., A.A. Gabel, S.M. Reed, R.M. Embertson, W.J. Tyznik and L.R. Bramlage. 1985. Correlation of dietary mineral to incidence and severity of metabolic bone disease in Ohio and Kentucky. Proc. Am. Assoc. Equine Practitioners. 445-461.

Krook, L. and J.E. Lowe. 1964. Nutritional secondary hyperparathyroidism in the horse. Pathol. Vet. Supplement 1. 1-98.

Law, J. 1901. Osteoporosis. Veterinary Med. 3:579.

Marshall, C.J. 1899. Osteoporosis. J. Comp. Med. Surg. 20:346-350.

Meyer, H. 1994. Cu-stoffwechsel und-bedarf des Pferdes. Übers. Tierenährg. 22. 363-394.

Meyer, H., M. Kirchgessner, K. Bronsch, H.H. Freese, H. Jeroch, J. Pallauf, E. Pfeffer and E. Schulz. 1994. Energi- und nährstoffvedarf landwirtschaftlicher nutztiere. Empfehlungen zue Energie- und Nährstoffversorgung der Pferde. 48.

National Research Council. 1973. Nutrient requirements of horses. 3rd Edition NRC-NAS. Washington, DC.

National Research Council. 1978. Nutrient requirements of horses. 4th Edition NRC-NAS. Washington, DC.

National Research Council. 1989. Nutrient requirements of horses. 5th Edition NRC-NAS. Washington, DC.

Pagan, J.D. 1994. Nutrient digestibility in horses. Proc. Feeding the Performance Horse:127.

Schryver, H.F., P.H. Craig and H.F. Hintz. 1970. Calcium metabolism in ponies fed varying levels of calcium. J. Nutr. 100:955.

Schryver, H.F., H.F. Hintz and P.H. Craig. 1971a. Calcium metabolism in ponies fed high phosphorus diet. J. Nutr. 101:259.

Schryver, H.F., H.F. Hintz and P.H. Craig. 1971b. Phosphorus metabolism in ponies fed varying levels of phosphorus. J. Nutr. 101:1257.

Schryver, H.F., H.F. Hintz, J.E. Lowe, R.L. Hintz, R.B. Harper and J.T. Reid. 1974. Mineral composition of the whole body, liver, and bone of young horses. J. Nutr. 104:126.

Schryver, H.F., O.T. Oftedal, J. Williams and H.F. Hintz. 1986. Lactation in the horse: The mineral composition of mare's milk. J. Nutr. 116:2142.

Stowell, S. 1858. Big head. Amer. Vet. J. 3:85-86.

Swartzmann, J.A., H.F. Hintz and H.F. Schryver. 1978. Inhibition of calcium absorption in ponies containing oxalic acid. Am. J. Vet . Res. 3:1621.

Whitlock, R.H., H.F. Schryver, L. Krook, H.F. Hintz and P.H. Craig. 1970. The effects of high dietary calcium for horses. P 127 in Proc. 16th Am. Assoc. Eq. Pract., F.J. Milne, ed. Lexington, Ky.