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Original Research

Effects of Excess Dietary Phosphorus on Fecal Phosphorus Excretion and Water Extractable Phosphorus in Horses

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ABSTRACT

Phosphorus excretion was studied in horses fed excess phosphorus. The hypothesis of this study was that the concentration of phosphorus and water extractable phosphorus (WEP) in the feces of sedentary horses would reflect the level of dietary phosphorus. Eight Standardbred mares were divided into two groups and received diets of grass hay and grain. The high phosphorus (HP) group received 142 g/d of monosodium phosphate (NaH_2PO_4), formulated to provide 4.5-times dietary phosphorus requirement, or 65-g phosphorus per day. The low phosphorus (LP) group received 28 g of phosphorus per day in the basal diet. These amounts were based on horses consuming 2% of body weight per day as hay plus supplemental grain. After a 7-day diet adaptation, a 5-day collection was conducted. Animals were housed from 4 PM until 8 AM the following morning without bedding during the collection period. After the first period, horses underwent a 10-day washout and then groups were crossed over for a second 7-day adaptation and 5-day collection. Feces was collected daily, weighed, and a 10% of aliquot taken. At the end of each collection period, feces was composited for each horse and analyzed for nitrogen, potassium, phosphorus, and WEP. Fecal phosphorus and WEP content were greater in the HP group (8.1 ± 0.3 vs. 6.8 ± 0.3 g/kg, respectively) than the LP group (3.6 ± 0.3 vs. 2.1 ± 0.3 g/kg, respectively; $P < .05$). Overfeeding a phosphorus supplement increased phosphorus and WEP in the manure; WEP may be useful for determining phosphorus runoff risk.

1. Introduction

Increased land application of phosphorus in manure resulting from overfeeding phosphorus can lead to eutrophication and other destructive influences to the environment [1,2]. Overfeeding of nutrients in the diet is one of the factors related to nutrient losses by animals [1]. Research with dairy cattle has indicated [3,4] that excretion of phosphorus can be reduced by dietary management. Swine and poultry research has shown that feeding modifications [5], use of low-phytate feedstuffs [6], or the use of phytase [7] can reduce phosphorus excretion; phytase is an enzyme that can break down indigestible phytate (high in phosphorus) in cereal grains and release phosphorus for use by swine or poultry. Phytase has been used in equine diets [8,9] with minor effects on phosphorus excretion.

Phosphorus from manure can build up in the soil [2] and run off into waterways resulting in harm to the environment; when phosphorus enters waterways, it can have an impact on aquatic plant growth and lead to eutrophication, a nutrient enrichment process that occurs in waterways as a result of excess phosphorus or nitrogen. It leads to excessive growth, and decay, of aquatic plants and may result in toxic conditions in waterway ecosystems.

The *Nutrient Requirements of Horses* [1] indicates that diet composition can influence the amount and composition of waste. Schryver et al [10] found that young ponies

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fed levels phosphorus up to five times the National Research Council recommended amounts had greater concentrations of phosphorus excretion; excretion was greater in feces but percentage increase was the greatest in urine. However, it is important to note that they also found high phosphorus (HP) retentions in these ponies. Increasing the levels of phosphorus may also affect other elements, for example decreased magnesium absorption [11].

The objective of this study was to evaluate the influence of excess dietary phosphorus, in the form of an inorganic, soluble supplement, on phosphorus excretion. Therefore, the hypothesis of this study was that the concentration of phosphorus and water extractable phosphorus (WEP) in the feces of sedentary horses would reflect the level of dietary phosphorus. Water extractable phosphorus has been evaluated previously to compare different materials on the basis of their potential to release soluble or extractable phosphorus to runoff water [12]; in addition to evaluating phosphorus levels in manure, samples were analyzed for WEP present.

2. Materials and Methods

2.1. Experimental Protocol

Eight Standardbred mares (aged 6–12 years, sedentary, nonpregnant, nonlactating) weighing 523.8 $\pm$ 14.6 kg and having a body condition score of 5.5 $\pm$ 0.1 were divided into two groups. All horses received a basal diet of 1 kg of grain and moderate quality grass hay per day at 2% of the horses' body weight (see Table 1 for nutrient content of grain and grass hay; analyzed by Dairy One Laboratory, Ithaca, NY). The HP group received a supplement, dosed orally (oral gavage), containing 142 g/d of monosodium phosphate (NaH_2PO_4; Sigma-Aldrich, St. Louis, MO). The supplement used, NaH_2PO_4, is readily soluble in water and has been reported to have a good bioavailability in other species [13,14]. The low phosphorus (LP) group received a basal diet containing 28 g of phosphorus per day, which is double the NRC recommended amount of 14 g of phosphorus for a 500-kg mature idle horse because of the fact that grass hay in the eastern United States is commonly very high in phosphorus. The HP group received 65 g of dietary phosphorus per day HP diets contained approximately 4.5 times the daily recommended phosphorus requirement [1]. All horses also had free choice access to a white salt block. After a 7-day dietary adaptation period, a 5-day collection was initiated. Horses in the HP group continued to receive supplements during the collection period.

After the dietary adaptation period, horse stalls (4 $\times$ 4 m) were stripped of bedding, and horses were housed on rubber mats. Horses were housed in stalls from 4 PM until 8 AM the following morning. Horses were turned out in two groups of four into dry lots from 8 AM to 4 PM. After a 5-day collection, the supplement was discontinued, and all horses were returned to a forage-only diet for 10 days to ensure no residual or carryover effects due to supplementation. At the end of this period, the groups were crossed over and began receiving HP and LP diets for another 7-day dietary adaptation period, and a 5-day collection was initiated as described. At each collection, stalls were stripped each day starting with a careful collection of feces only, which was weighed and a 10% of aliquot taken. Once all the feces was removed from the stalls, the remaining urine waste was removed and disposed of. At the end of the 5 days, collection samples were frozen until further analysis. Before analysis, a composite sample was created for each horse, dried, and sent for manure analysis; samples were also analyzed for WEP. Water extractable phosphorus is an estimate of soluble or extractable phosphorus in manure. This was completed using the procedure of Wolf et al [12].

Table 1
Nutrient composition of feeds (dry matter basis).

Nutrient	Grain[a]	Grass Hay[a]
Dry Matter, %	88.7	93.4
Horse digestible energy, Mcal/kg	3.28	1.83
Crude protein, %	17.5	8.7
Acid detergent fiber, %	14.2	44.0
Neutral detergent fiber, %	24.8	71.3
Calcium, %	1.28	0.41
Phosphorus, %	0.91	0.19
Magnesium, %	0.33	0.11
Potassium, %	1.11	2.07
Sodium, %	0.37	0.005
Iron, ppm	305	79
Zinc, ppm	163	22
Copper, ppm	34	10
Manganese, ppm	142	37

[a] Analyzed by the Dairy One Forage Laboratory, Ithaca, NY.

2.1.1. Analytical Methods

Nitrogen, phosphorus, and potassium analysis were completed at the Dairy One Laboratories, Ithaca, NY. Nitrogen analysis was by combustion using a Leco TruMac N Macro Determinator (Leco Corporation, St. Joseph, MI) [15]. Phosphorus and potassium samples were predigested at ambient temperature for 15 minutes with 8 mL of nitric acid (HNO_3) and 2 mL of hydrochloric acid (HCl), then increased to 190°C over 15 minutes, and held at digestion temperature of 190°C for 15 minutes. Vessels were brought to 50-mL volume, and an aliquot was used for analysis on an inductively coupled plasma (ICP) radial spectrometer (CEM Application Note for Acid Digestion, Matthews, NC) [16].

Water extractable phosphorus analysis was competed at the Rutgers University Soil Testing Laboratory (New Brunswick, NJ). Samples were analyzed by taking a 2.0-g dry sample of manure, adding 200 mL of water, and shaking for 60 minutes followed by centrifuging (3,000 rpm for 10 minutes) and filtering through No. 40 Whatman filter paper. The remaining liquid supernatant was analyzed on an ICP radial spectrometer [12]. The samples were corrected to a dry weight basis.

2.1.2. Statistical Analysis

All data were analyzed by analysis of variance using the NCSS LLC system [17]. Because there were no differences ($P > .05$) between crossover periods, results were pooled and treatments were compared with untreated control.

3. Results

All horses maintained their body weight and body condition throughout the course of the study. Horses in the