CALCIUM METABOLISM IN RABBITS

by Leah Postman, DVM

Calcium is a common mineral element which is fundamental to many normal bodily functions. Of the 15 known essential mineral nutrients, calcium is the one found in largest amounts in animals, and therefore is required in the largest amounts. Almost all (99%) of the total body calcium is found within the bones and teeth. While most mammals make one or two sets of teeth to last a lifetime, rabbits and horses continually form and wear down their teeth throughout their life span. For rabbits, continual tooth eruption is a factor in long-term calcium requirements. The other 1% of body calcium supports critical metabolic functions, including nerve impulse conduction, muscle contraction, heart rate and contraction, and blood clotting.

Most mammalian species follow a similar pattern of calcium metabolism. While rabbits do not follow the typical mammalian prototype, I will describe it for comparison purposes. After calcium is eaten, it is absorbed by the small blood vessels supplying the intestines, into the bloodstream. The level of calcium in the blood is closely controlled by two hormones: parathyroid hormone and calcitonin. These two hormones act in tandem to keep calcium levels within the blood optimally balanced. Parathyroid hormone (parathormone, PTH) is produced by the parathyroid glands: tiny glands located adjacent to the thyroid glands. When the parathyroid detects that the level of calcium in the blood is getting too low, it secretes extra PTH. This increased level of PTH in the blood acts on cells in the kidney to stimulate formation of an active form of Vitamin D. This activated Vitamin D in turn acts on cells in the intestine to increase calcium binding capacity. In this way, more of the ingested calcium is picked up by the intestines, and the low blood calcium is corrected by increased intestinal absorption. This intricate loop acts to protect animals from the potentially deadly consequences of low blood calcium -- heart attacks, seizures, and muscular tetany.

Just as too little calcium in the blood can be dangerous, so can too much. To protect against elevations in the blood calcium level, the thyroid glands produce calcitonin. The thyroid produces more calcitonin when it senses an increase in circulating calcium. This increased level of calcitonin acts on cells within the bones to increase absorption of calcium into the bones. The calcium within bones not only provides structural integrity, but serves as a reserve supply for the body, should nutritional sources of calcium become scarce. Just as PTH protects animals from the consequences of LOW circulating levels of calcium, calcitonin protects animals from the consequences of HIGH circulating levels of calcium-- seizures, mineralization of tissues and blood vessels.

Rabbits metabolize calcium very differently from other animals. Unlike other mammals, rabbits' blood calcium levels fluctuate widely, dependent upon the level of calcium in their diet. Rabbits also have very complete intestinal absorption, and thereby end up with blood calcium levels that are generally higher than other mammals. Although Vitamin D mediates intestinal absorption of calcium in most mammals, intestinal calcium absorption in rabbits is apparently independent of Vitamin D. Only rarely, in conjunction with the changes in calcium metabolism associated with birth and the high calcium requirements of lactation, do their calcium levels drop to a dangerous level, resulting in tetany. On a

practical level, for the spayed house bunny, this is not a concern. What is a concern however, is the upper end of the blood calcium range.

In other mammals, the thyroid-produced hormone calcitonin acts to lower blood calcium levels, to keep them below a ceiling value. This type of control does not seem to exist in rabbits. Their blood calcium levels become elevated in direct proportion to the calcium consumed in their diet. To make the bunny calcium situation even more of a conundrum, rabbits are even more unusual because they, being inherently prone to elevations in blood calcium, filter excess calcium through their kidneys, and excrete it through their urine. Whereas most mammals can rid their bodies of excess calcium efficiently and without adverse effects through bile and intestinal secretion, bunnies apparently cannot. Studies on pika, jackrabbits and mountain hare have demonstrated that the wild lagomorph relatives of domestic rabbits share this pattern of urinary excretion of calcium.

The kidney's serve as the body's filtration system -- to discard waste products, to conserve normal levels of electrolytes within the body, and to regulate water balance. To accomplish this, incoming blood is juxtaposed with a network of fine tubules, across which filtration occurs. The delicate tissues within the kidneys are ideally suited to filtering soluble substances --ions, glucose, proteins. But once the kidneys have reached their (limited) capacity for reabsorption, calcium precipitates within the urine, and is excreted as insoluble crystalline salts. This is what is in that cloudy white urine ("sludge"), or gritty puddles that you may have cleaned. It has been theorized -- not proven yet -- that the red pigment often seen in rabbit urine, although not blood, is a blood pigment indicating damage to the kidneys' tubules, most likely by calcium salts. Some feel that "red urine" is caused by harmless plant pigments, and is in no way a problem.

We do know that calcium stones are a significant problem for pet rabbits. These stones can be found anywhere within the urinary tract -- kidneys, ureters, bladder, urethra. Depending on their location, they can be painful and often require surgical removal. And they can be very difficult to remove. We also know that urinary excretion of calcium correlates directly with the level of calcium in the diet. In other words, the more calcium that the bunnies eat, the more their kidneys process and eliminate. Given the potentially serious, and all-too-common problems associated with calcium excess, it makes sense to provide no more calcium than what is needed for maintenance of skeletal and neuromuscular needs.

There are two standard sources for determining rabbits' nutritional requirements: the National Research Council (NRC, 1977) and Francois Lebas (Lebas, 1980), both referenced in Cheeke's _Rabbit Feeding and Nutrition_, 1987. The NRC did not determine the maintenance requirement for calcium, but sets 0.4% as the growth requirement; maintenance should be considerably less. Lebas determined the maintenance requirement to be 0.6%. Based on this data, current recommendations are for a calcium content of 0.4% to 0.6% (dry matter basis). Almost all of the commercial pellets currently available exceed this, some by almost double.

All of these pellets share a common trait -- they are formulated primarily from alfalfa meal. And alfalfa meal, like the alfalfa hay from which it is made, has a very high calcium content -- 1.5%. So it is a challenge to make a pellet that starts with alfalfa -- inherently high in calcium, and dilute the calcium

content by 60%. There is really only one pellet that avoids this formulation dilemma. Oxbow Hay Company's Bunny Basics/T starts out with Timothy meal, not alfalfa meal, and thereby produces a pellet with 0.4-0.8% calcium.

The other potentially significant source of calcium in rabbits' diets is fresh greens. Although many people worry about the greens noted for high calcium content -- kale, spinach, collards -- I do not. All fresh greens are about 70% to 85% water, which greatly dilutes all nutrients. To eliminate the potential to misrepresent nutrient content due to variability in water content, it is essential to compare calcium content on a dry matter basis, which is how the nutrient requirements are expressed on labels and in tables. For example, kale, which many recommend avoiding by virtue of its calcium content, has 1.6% calcium on a dry weight basis. In other words, dehydrated kale has roughly three times the NRC recommended calcium content. However, the fresh bunch of kale is mostly water, so the calcium content drops dramatically, to 0.24% when fed fresh. If you were to feed a medium-sized (5 pound) bunny 1/4 cup (about 60 grams) of a pellet meeting NRC recommendations, he would consume about 0.30 grams of calcium. To obtain a similar quantity of calcium from kale, the bun would have to eat over 4 ounces (130 grams) of kale. That is a sizable pile of kale -- about as much as you could stuff in a half gallon milk carton. Similarly, dandelion greens, have a calcium level of 1.6% on a dry matter basis. But since our bunnies eat them fresh, they are only getting 0.20% calcium. Again, we see that even for greens with a relatively high calcium content, the calcium level of the leaves the bun is munching is actually quite low.

So, what does all this mean in real life? It mean's that to protect a rabbit's kidneys from calcium overload, we must minimize the calcium we feed them. Alfalfa -- both hay and alfalfa meal derived pellets -- is the biggest source of calcium overload for domestic bunnies. Minimizing the alfalfa in rabbits' diets will automatically reduce their calcium levels. While some veterinarians (notably, Dr. Susan Brown) may recommend eliminating pellets entirely from the house rabbit's diet, I do not. I think a balanced pellet, fed in limited quantities, can help even out the fluctuations inherent to hay -- soil content, day length, first cutting vs. second cutting, etc.

From my point of view, there is one preferred pellet -- Oxbow Bunny Basics/T. Oxbow has been the only manufacturer to date to realize that basing a pellet on Timothy hay just fundamentally makes more sense. Although there are a few alfalfa meal based pellets with a reasonably low calcium content, they do not have the fiber content of Bunny Basics/T (29%), so on the fiber count they don't stack up. I think Bunny Basics/T is the best thing to happen to bunnies since Farmer McGregor retired. Of course, good quality grass hay should be the bulk of your rabbit's diet, with fresh greens for variety, added fluids and vitamins. I believe that this combination of feeds offers the best available complete nutritional profile, as well as taking into account a rabbit's idiosyncratic calcium metabolism, and minimizing the risk of associated urinary tract disease.