South Dakota State University
Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange

South Dakota Sheep Field Day Research Reports, 1970

Animal Science Reports

1970

Phosphatic Urinary Calculi

Royce J. Emerick
South Dakota State University

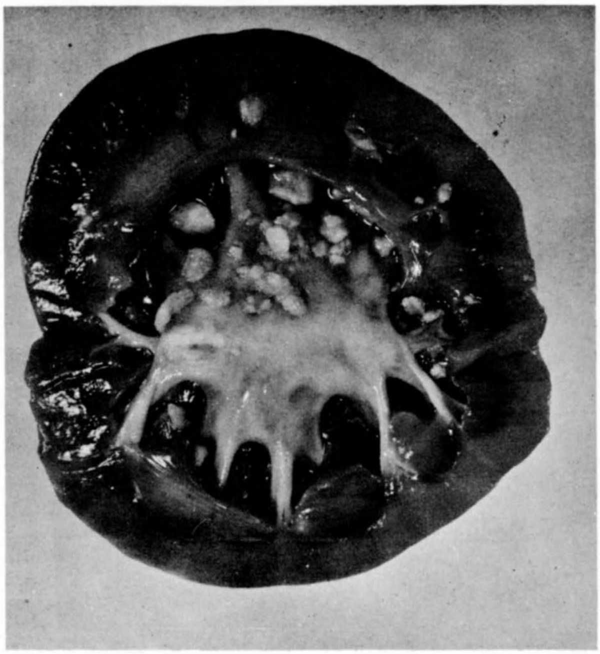
Lawrence B. Embry

Follow this and additional works at: http://openprairie.sdstate.edu/sd_sheepday_1970

Recommended Citation

Emerick, Royce J. and Embry, Lawrence B., "Phosphatic Urinary Calculi" (1970). *South Dakota Sheep Field Day Research Reports, 1970.* Paper 12.
http://openprairie.sdstate.edu/sd_sheepday_1970/12

This Report is brought to you for free and open access by the Animal Science Reports at Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. It has been accepted for inclusion in South Dakota Sheep Field Day Research Reports, 1970 by an authorized administrator of Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. For more information, please contact michael.biondo@sdstate.edu.



Sheep kidney opened bilaterally exposing phosphatic calculi.

Phosphatic Urinary Calculi

By Royce J. Emerick, professor of station biochemistry, and Lawrence B. Embry, professor of animal science.

Reprinted from South Dakota *Farm & Home Research*, Vol. XX, No. 1, Winter 1969, Agricultural Experiment Station, South Dakota State University, Brookings.

URINARY calculi is a term used to refer to mineral deposits occurring within the urinary tract. Other terms, urolithiasis and "water belly," are also used to describe this disease or the conditions that develop as a consequence of it. Often specific names designating the location of the stones are assigned — kidney stones, bladder stones and urethral stones.

The economic impact of this nutritional disease is great and many livestock feeders have experienced it first hand. Its occurrence is generally sporadic. Single animals may be lost at irregular intervals throughout a feeding period. In more extreme instances, large numbers of animals may succumb in a period of a few days. In some feedlots losses of 5% to 10% are not uncommon and may go higher in other cases. Losses generally involve male or castrated male sheep and cattle. While mineral deposits may be found in the urinary tracts of females, the deposits seldom result in blockage of the urinary tract, a condition to which the loss of male animals afflicted with urinary calculi is attributed.

With few exceptions, urinary calculi formed under feedlot conditions are composed of various phosphates including calcium, magnesium and ammonium phosphates. In contrast, those occurring in range animals usually have silica as the main constituent. Both types occur in a variety of sizes and shapes with the phosphate deposits often occurring in very large quantities.

Many questions as to the cause, prevention and treatment of urinary calculi remain yet unanswered. However, many experiments the past several years provide a basis for a greater understanding of this problem and its control.

Symptoms

At first, animals afflicted with urinary calculi may appear restless with frequent straining in an unsuccessful attempt to urinate. They may repeatedly stamp their feet and kick at the abdomen. In some cases when urinary blockage is not complete, urine may dribble slowly from the sheath. Upon failure to pass the stone and after complete blockage of urine flow, the bladder or urethra finally ruptures releasing urine into the body cavity or surrounding tissues resulting in the condition often called "water bellly." At this stage the animal may show a complete loss of appetite and stand quietly or lie down, being very reluctant to rise. Death due to uremic poisoning ensues. Postmortem examination generally reveals blood-tinged fluid in the body cavity, inflammation of the urinary tract and a hemorrhagic condition at the point of rupture.

Treatments

Attempts to treat recognized cases of urinary calculi usually meet with limited success. A stone passed by an animal often represents only a portion of the calculi present in the bladder; thus, the chance of a reoccurrence is great. If recognized in the early stages, an animal afflicted with urinary calculi may be sold for slaughter.

Treatments designed to facilitate passing or dissolving the deposit have generally been unsuccessful. Surgery represents the most effective treatment. In rams or wethers, close examination will sometimes show the point of blockage to be in the filamentous urethral process (see diagram of urinary tract). If this is the case, the process and the accompanying stone may be successfully removed surgically.

In steers, the urethra may be surgically bisected at a point above the sigmoid flexure and brought to the outside of the body to by-pass the more constricted portion of the tract. Steers treated in this manner often make acceptable weight gains for the remainder of the feeding period. However, this operation requires the skill of an experienced veterinarian, and economics rarely allow its application to sheep.

Major Causative Factors

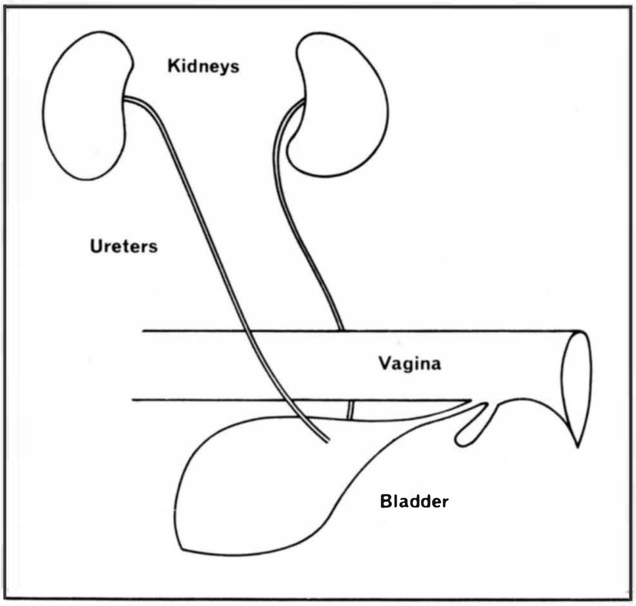
High urinary phosphorus levels. In early work, an association was observed between high urinary phosphorus levels and the formation of phosphatic urinary calculi. Since that time, dietary phosphorus levels of 0.5% to 0.6%, representing about a two-fold increase over normal levels, have been used repeatedly for the experimental production of about a 50% incidence of urinary calculi in lambs. In subsequent experiments, no other single factor has been found to be of comparable importance. In addition to the level of phosphorus in the ration, its nutritional availability and the calcium-to-phosphorus ratio greatly influence the extent to which phosphorus is excreted in the urine.

The need for phosphorus supplementation of many classes of livestock under a variety of conditions cannot be disputed. However, the concentrate feedstuffs (such as grains, oil meals, etc.), normally fed at high levels to feedlot cattle and sheep, generally provide levels of phosphorus in excess of those required for optimum weight gains. Supplementing this type of ration with additional phosphorus, whether fed as part of the concentrate mix or free choice, requires that special attention be given to the calcium-to-phosphorus ratio if losses from urinary calculi are to be avoided.

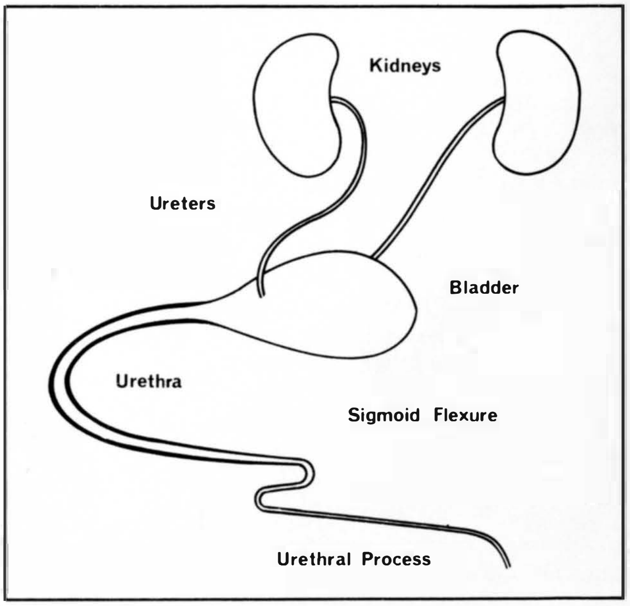
Calcium levels in high-concentrate finishing rations are generally low. This may be corrected by feeding a good quality legume forage (alfalfa hay) or a more concentrated source of calcium (ground limestone). The amounts required are discussed later.

Urine alkalinity. The various phosphates comprising urinary calculi formed under feedlot conditions generally represent materials that have precipitated from an alkaline urine. The urine of cattle and sheep is normally alkaline, although to various degrees. The degree of alkalinity (measured as pH) is determined to a large extent by the

Urinary tracts, female (left), male (right).



Female Urinary Tract



Male Urinary Tract

nature of the ration. However, the extent to which a given feed will contribute to urine alkalinity cannot be surmised from the initial acidity or alkalinity of the ration ingredients. The acidity associated with plants and plant fermentation products (such as silage, natural vinegars, etc.), is metabolized in the body and does not reach the urine except in the form of degradation products. The net result is that most forages contribute toward an alkaline urine, cereal grains have little influence and feeds having a high content of natural protein contribute some degree of acidity. In the latter instance, the acid-forming effect is due to the sulfur and other acid-forming elements inherent in natural proteins. On the other hand, molasses contains much of the soluble alkali-forming mineral constituents of the plant from which it was made and contributes strongly to the alkaline constituents of urine.

The use of alkaline buffering agents, presumably to increase consumption and utilization of high- or all-concentrate diets, has received considerable attention by research workers in recent years. Feeding 2% sodium bicarbonate in an all-concentrate lamb ration consisting principally of corn and soybean meal resulted in an increase in urine alkalinity and subsequent urinary calculi formation in more than one-half of the lambs. The calculi incidence was even higher when this treatment also included an above-normal level of phosphorus.

Low urine volume. Variations in urine volume inversely affect the relative concentration of minerals and other excretory products in the urine; an increase in urine volume tends to dilute these products. Urine volume is to a great extent a reflection of water consumption. A lower water consumption and subsequently greater concentration of urinary constituents occurring in animals on feed during the winter is believed to be an important reason for the high urinary calculi incidence associated with this season.

While the importance of low urine volumes in the etiology of urinary calculi cannot be disputed, research has shown that a low urine volume alone is not sufficient to promote stone formation.

Factors of Limited or Doubtful Importance

Diethylstilbestrol (DES). This estrogenic hormone is used extensively to increase rate of gain in feedlot cattle and lambs. Early experiments utilizing DES implicated it as a cause of urinary calculi. However, early experiments employed 15- and 30-milligram implants for lambs, these being levels capable of causing significant changes in the urogenital system of treated lambs. Also, these levels are five to ten times higher than those currently approved for use.

In multiple experiments, lambs on control and high-phosphorus calculogenic diets were implanted with 3 milligrams of DES or fed 2 milligrams per head daily without evidence of an increase in the incidence of urinary calculi. These represent levels that are currently in common usage. Thus, as it is now commonly used, DES does not appear to be a contributing factor in urinary calculi.

Vitamin A. A deficiency of vitamin A has been thought to represent a primary cause of urinary calculi. Changes in epithelial tissue including the lining of the urinary tract, and an increase in susceptibility to infections under conditions of vitamin A deficiency provide a basis for these beliefs. However, experiments designed to determine whether or not vitamin A deficiency is a specific causative factor have yielded largely negative results. While such a deficiency may contribute to the urinary calculi problem, it probably is not of major importance in the large incidence of urinary calculi occurring in feedlots across the nation. Also, assignment of a calculi-protective effect to the feeding of a large excess of vitamin A appears to have no sound basis.

Magnesium. An inverse relationship between urinary magnesium levels and the incidence of urinary calculi has been observed by some research workers. However, increases in dietary phosphorus are known to reduce urinary magnesium excretion. Feeding 0.2% magnesium (as magnesium oxide) with a high-phosphorus calculogenic ration gave no more protection than was provided by a comparable level of calcium. Variations in magnesium metabolism appear to be of doubtful importance in the causation of urinary calculi.

Hard water. In instances of urinary calculi outbreaks, attention is often focused upon the source of drinking water. However, assuming an adequate supply of potable water, there is no basis for an involvement of variations in water quality. Further, the minerals (calcium and magnesium) contributing to water "hardness" are among the factors found to be protective against phosphatic urinary calculi.

Other factors. Specific factors including hormone imbalances and certain B-vitamin deficiencies have been implicated in urinary calculi formation in laboratory animals, principally the albino rat. However, these do not appear to warrant attention as important causative factors of urinary calculi in feedlot cattle and sheep.

Prevention

General considerations. Urine blockage due to urinary calculi in growing-fattening wethers or steers may occur at any time during the feeding period, but most losses occur after the animals have been on feed for at least 3 weeks. Preventive measures taken after outbreaks of calculi have occured may appear to be only partially effective in that the stones already formed may lodge in the urethra and cause urine blockage at a later date.

In some instances, siliceous deposits apparently formed during the period that the animals were maintained on the range have been found in the urinary tracts of sheep and cattle at slaughter following an extensive period in the feedlot. Urinary deposits of this type were found in as many as 25% of some groups of sheep and cattle

completing feeding trials at the South Dakota Agricultural Experiment Station. While these may cause no difficulty, they represent a potential problem.

Siliceous calculi have been known to form in animals maintained in drylot and fed feeds such as grass hay, straw or oat grain having a high silica content. For this reason and because other types may form under certain conditions, a positive identification of the type of calculi being encountered is especially important in planning a long-range program for calculi prevention. However, the phosphatic type of urinary calculi is by far the type most commonly encountered in feedlot animals, and each ration should be planned to minimize losses from this cause.

Most materials and practices offering some degree of protection against phosphatic urinary calculi appear to involve at least one of the following mechanisms: (1) a lowering of urinary phosphorus levels; (2) acidification of the urine; (3) and an increase in urine volume. Although other modes of action have been postulated, there is very little conclusive evidence in their support at present.

Control of ration phosphorus levels and calcium-to-phosphorus ratios. Of the various methods used successfully for urinary calculi prevention under experimental conditions, the use of proper phosphorus levels and calcium-to-phosphorus ratios appear to be the most applicable to practical feedlot conditions. Attention should be given to this aspect of urinary calculi prevention before other methods are applied.

The phosphorus requirements of fattening lambs and cattle range from 0.16% to 0.23% of the ration as stated by the National Research Council. Average calcium and phosphorus values of some of the common feeds are shown in table 1. It is evident from these data that the phosphorus content of high-concentrate finishing rations will frequently exceed required levels without phosphorus supplementation. However, assuming the accuracy of some of the published minimum values for the phosphorus content of cereal grains, phosphorus supplementation of beef cattle and lamb finishing rations may be an important consideration in feedlots relying upon areas of low phosphorus fertility for feed supplies. In these instances, the addition of a phosphorus supplement—such as dicalcium phosphate, defluorinated rock phosphate or steamed bone meal—may be advisable.

After ample phosphorus intake is assured and an attempt has been made to avoid excessive levels, attention must be given to the level of calcium and its ratio to phosphorus if potential losses from urinary calculi are to be minimized. Use of ground limestone to provide a ratio of 2 to 2.5 parts of calcium to 1 part of phosphorus in lamb rations containing excessive phosphorus has proved effective in lowering blood and urinary phosphorus levels as well as providing a high degree of protection against urinary calculi.

Table 1. Average calcium and phosphorus contents of some common feedstuffs*

Feedstuff	Calcium	Phosphorus
	%	%
Grains and grain products		
Barley	0.08	0.42
Corn	0.03	0.27
Linseed meal	0.40	0.83
Oats	0.10	0.35
Sorghum	0.04	0.31
Soybean meal	0.32	0.67
Wheat	0.05	0.36
Wheat bran	0.14	1.17
Dry roughages		
Alfalfa hay	1.48	0.23
Bromegrass hay	0.39	0.25
Oat hay	0.23	0.21
Prairie hay	0.38	0.11
Timothy hay	0.32	0.17
Silages†		
Alfalfa	0.49	0.12
Corn	0.08	0.06
Sorghum	0.10	0.06
Minerals		
Limestone	33.84	0.02
Dicalcium phosphate	27.00	19.07
Bone meal	29.98	13.59

*From NRC Publication No. 1232, 1964, Joint United States-Canadian Tables of Feed Composition. National Academy of Sciences, Washington, D. C.

†About 3 lb. of silage is required to give 1 lb. of air-dried feed.

Although it is preferable to use actual calcium and phosphorus values, obtained by analysis in calculating the amount of calcium to add, average values obtained from tables of feedstuff composition may generally suffice. As a rule of thumb, the following approximation is applicable: Add 1.5% to 2% ground limestone to high-concentrate beef cattle or lamb rations. Reduce this amount by one-half if the ration contains as much as 20% to 25% of a good quality legume forage.

Feeding calcium and phosphorus supplements free choice is considered to be less desirable than mixing known amounts directly into the ration. When free-choice feeding of these materials is practiced, the same points emphasized above should be given consideration, that is, an excessive intake of phosphorus should be avoided and a high calcium-to-phosphorus ratio should be achieved.

Reducing the alkalinity of the urine. As urine alkalinity is an important causative factor in formation of phosphatic urinary calculi, some protection is provided by feeding materials having an acid-forming effect. Ammonium chloride and calcium chloride are coming into use for this purpose. Feeding ammonium chloride for prevention of urinary calculi is currently limited to 0.25 of an ounce per head daily for sheep and 1 to 1.5 ounces for fattening cattle. It is important that the ammonium chloride be mixed thoroughly into the concentrate mixture to avoid palatability problems associated with higher concentrations of this material.

On an equal weight basis, ammonium chloride appears to be more effective than calcium chloride in reducing alkalinity of the urine and in controlling urinary calculi. While 1% ammonium chloride has appeared to depress feed consumption, this level of calcium chloride (as anhydrous $CaCl_2$) did not. However, 1% calcium chloride was found to be highly effective in reducing the incidence of urinary calculi. In a hydrated form as it is most readily available commercially ($CaCl_2 \cdot 2H_2O$), a level of 1.3% is equivalent to 1% of the anhydrous material. In addition to the acid-forming effect, calcium chloride fed at this level provides calcium equal to that provided by levels of 0.9% to 1% of most sources of ground limestone.

Feeding materials having an acid-forming effect for calculi prevention probably have greatest application in certain feedlots where it may not be possible or feasible to practice strict control of phosphorus levels and calcium-to-phosphorus ratios. Further, it must be recognized that while these compounds may be valuable tools for calculi prevention, their use does not substitute for sound nutritional practices.

It should be noted that feeding potassium chloride does not contribute to acidification of the urine and when fed as 1% of the ration it generally has no significant effect on urine volume. In a few instances, some degree of protection against urinary calculi has been reported for the feeding of potassium chloride. In other instances, detrimental effects have been associated with its use. Presently, there is no sound basis for the use of potassium chloride in urinary calculi prevention programs.

Increasing urine volume. Feeding 4% common salt (sodium chloride) in lamb rations has been observed to increase water consumption sufficiently to yield approximately a two-fold increase in urine volume. Results from its use have not been sufficiently satisfactory to justify reliance upon this method of prevention under conditions that favor a high incidence of urinary calculi. However, its use as an adjunct to other methods outlined herein may be valuable.

SUMMARY

Principal causes of phosphatic urinary calculi.

1. High urinary phosphorus concentrations.
   a. A high intake of dietary phosphorus.
   b. A low calcium to phosphorus ratio.
2. Urine alkalinity
   a. Normal alkali-forming effect of most plant materials.
   b. Alkali-forming effect of certain salts, i.e., sodium bicarbonate.

Methods recommended for prevention of phosphatic urinary calculi. (These are based on data obtained with sheep, but are believed to also apply to cattle).

1. Practice strict control of dietary phosphorus levels, avoid a large excess.

2. Feed additional calcium (ground limestone is commonly used) maintaining a calcium to phosphorus ratio between 2:1 and 2.5:1. This may be done by adding 1.5% to 2% ground limestone to high-concentrate rations, reducing this amount by one-half if the ration contains as much as 20% of a good quality legume forage.

3. Feed acid-forming salts. Ammonium chloride fed daily at a rate of 7.1 grams (0.25 of an ounce) to sheep, or 28.4 to 42.5 grams (1.0 to 1.5 ounces) to fattening cattle, has been approved by the Food and Drug Administration for this purpose. These quantities will generally yield a level less than the 1% reported herein to be highly effective in urinary calculi prevention. Calcium chloride fed at a level of 1% of the diet (equivalent to 1.3% $CaCl_2 \cdot 2H_2O$), while highly effective in reducing the incidence of urinary calculi in South Dakota studies has not been approved by the FDA to be sold for use as the active ingredient in feeds used for calculi prevention.

4. Recommendations pertaining to phosphorus and calcium levels, outlined above under recommendations 1 and 2, should be followed as a regular feeding practice. Those listed under item 3, pertaining to the feeding of acid-forming salts, should be applied principally in problem areas where complete calculi prevention is not achieved through application of the other recommended practices. Along with these recommendations, it is assumed that the livestock feeder will provide rations adequate in all of the essential nutrients and supply an adequate amount of fresh water.□

REFERENCES

Research pertaining to certain phases of this discussion is presented in detail in the following scientific publications:

Emerick, R. J., L. B. Embry and O. E. Olson. Effect of sodium silicate on the development of urinary calculi and the excretion of various urinary constituents in sheep. J. Animal Sci. 18:1025-1030, 1959.

Emerick, R. J. and L. B. Embry. Calcium and phosphorus levels related to the development of phosphate urinary calculi in sheep. J. Animal Sci. 22:510-513, 1963.

Emerick, R. J. and L. B. Embry. Effects of calcium and phosphorus levels and diethylstilbestrol on urinary calculi incidence and feedlot performance of lambs. J. Animal Sci. 23:1079-1083, 1964.

Bushman, D. H., R. J. Emerick and L. B. Embry. Incidence of urinary calculi in sheep as affected by various dietary phosphates. J. Animal Sci. 24:671-675, 1965.

Bushman, D. H., R. J. Emerick and L. B. Embry. Experimentally induced ovine phosphatic urolithiasis: Relationships involving dietary calcium, phosphorus and magnesium. J. Nutrition 87:499-504, 1965.

Bushman, D. H., L. B. Embry and R. J. Emerick. Efficacy of various chlorides and calcium carbonate in the prevention of urinary calculi. J. Animal Sci. 26:1199-1204, 1967.

Bushman, D. H., R. J. Emerick and L. B. Embry. Effect of various chlorides and calcium carbonate on calcium, phosphorus, sodium, potassium and chloride balance and their relationship to urinary calculi in lambs. J. Animal Sci. 27:490-496, 1968.

Hoar, D. W., R. J. Emerick and L. B. Embry. Ovine phosphatic urolithiasis as related to the phosphorus and calcium content and acid-base-forming effects of all-concentrate diets. J. Animal Sci. (Submitted for publication).