Influence of Diet on Urinary pH, Urine and Serum Biochemical Variables, and Blood-Ionized Calcium Concentrations in Healthy Dogs*

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ABSTRACT

Urolithiasis is a common cause of lower urinary tract disease in dogs. Diet influences urine composition, and dietary change is often incorporated into medical management of uroliths. The purpose of this study was to determine the influence of four diets on urine pH in healthy dogs. Sixteen adult dogs of various breeds, ages, and weights were fed four diets in Latin Square design: a diet formulated for adult dogs at maintenance (Diet A; ProPlan Canine Chicken and Rice Adult [dry], Ralston Purina Co, St. Louis, MO); a diet formulated to aid in management of fiber-responsive diseases (Diet B; CNM Canine DCO [dry], Ralston Purina Co, St. Louis, MO); a diet formulated to aid in management of chronic renal failure (Diet C; CNM Canine NF [dry], Ralston Purina Co, St. Louis, MO); and a diet designed to aid in prevention of struvite urolithiasis (Diet D; Prescription Diet Canine c/d [dry], Hill’s Pet Nutrition Inc, Topeka, KS). Diets were fed for 21 days. On day 21, blood and urine samples were collected before feeding one-half of daily caloric requirements, and urine was collected 4 and 8 hours later. A biochemical analysis and ionized-calcium test were conducted on blood samples, and a complete urinalysis and urine pH determined by a pH-electrode were conducted on urine samples. Thirteen dogs completed the study. Serum phosphorous concentrations were
significantly lower and urine pH was significantly higher when dogs consumed Diet C when compared with the other three diets. A postprandial effect on urine pH was not demonstrated when dogs consumed any diet. Other urinalysis parameters were not different between dogs or diets. Diet does influence urine pH in healthy dogs; however, healthy dogs produced urine with an acidic pH except while consuming a diet specifically formulated to produce alkaluria. Furthermore, crystalluria was commonly found in these healthy dogs regardless of the diet.

# INTRODUCTION

Urolithiasis is a common cause of lower urinary tract disease in dogs and was diagnosed in 3638 of 676,668 dogs (0.53%) admitted to veterinary teaching hospitals in North America between 1980 and 1993. The most commonly found mineral in canine uroliths is magnesium ammonium phosphate hexahydrate (struvite). For struvite uroliths to form, urine must be oversaturated with magnesium, ammonium, and phosphate ions. Furthermore, pH influences struvite solubility; struvite is more soluble in urine with a pH <6.8 and less soluble and therefore more likely to precipitate in urine with a pH ≥6.8. There are two types of struvite uroliths: those that form because of a bacterial urinary tract infection (infection-induced struvite) and those that form in the absence of a bacterial urinary tract infection (sterile struvite). In cats, sterile struvite uroliths occur more commonly than infection-induced struvite uroliths; however, in dogs, infection-induced struvite uroliths occur more commonly.

Dietary modification may be important in the medical management of struvite uroliths. Consumption of a diet restricted in protein, phosphorous, and magnesium and containing a urinary acidifier when compared with maintenance adult foods is reported to promote struvite urolith dissolution in dogs and cats. In cats, dietary modification is thought to be important in preventing sterile struvite recurrence. The role of diet in preventing infection-induced struvite uroliths is less clear. Because struvite is more soluble in acidic urine in cats, researchers have extrapolated that consumption of diets inducing aciduria might be beneficial in dogs as well. The purpose of this study was to determine the influence of four diets on urine pH in healthy dogs.

# MATERIALS AND METHODS

## Dogs

Sixteen adult dogs of various breeds, 1 to 12.5 years, and weighing 2.2 to 55 kg, were recruited from faculty, staff, and students at The University of Georgia College of Veterinary Medicine (Table 1). All were considered to be healthy based on results of historical information, physical examination, complete blood cell count, serum biochemical analyses (urea nitrogen, creatinine, phosphorous, calcium, sodium, potassium, chloride, total carbon dioxide, albumin, total protein, glucose and bilirubin concentrations, and activities of alanine aminotransferase and alkaline phosphatase), and a complete urinalysis and aerobic bacteriologic culture of urine obtained by cystocentesis. The University of Georgia Animal Use and Care Committee approved the study.

## Diets

Single batches of four commercially available, dry canine diets were used, including a diet formulated for adult dogs at maintenance (Diet A; ProPlan Canine Chicken and Rice Adult [dry], Ralston Purina Co, St. Louis, MO), a diet formulated to aid management of fiber-responsive diseases (Diet B; CNM Canine DCO [dry], Ralston Purina Co, St. Louis,
MO), a diet formulated to aid management of chronic renal failure (Diet C; CNM Canine NF [dry], Ralston Purina Co, St. Louis, MO), and a diet designed to aid prevention of struvite urolithiasis (Diet D; Prescription Diet Canine c/d [dry], Hill’s Pet Nutrition Inc, Topeka, KS). All diets were formulated between January 1 and July 1, 1996. Nutritional characteristics of the diets are presented in Table 2. Diets were packaged in plain white bags so that pet owners and investigators would not know which diet was fed.

### TABLE 1. Demographics of 13 Dogs Evaluated in the Study

<table>
<thead>
<tr>
<th>Breed</th>
<th>Age (years)</th>
<th>Weight (kg)</th>
<th>Reproductive Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walker tree hound</td>
<td>Unknown (adult)</td>
<td>16.4</td>
<td>Male, intact</td>
</tr>
<tr>
<td>Mixed breed</td>
<td>3</td>
<td>26.4</td>
<td>Female, spayed</td>
</tr>
<tr>
<td>German shorthaired pointer</td>
<td>5</td>
<td>34.1</td>
<td>Female, spayed</td>
</tr>
<tr>
<td>Mixed breed</td>
<td>1</td>
<td>12.7</td>
<td>Female, spayed</td>
</tr>
<tr>
<td>Golden retriever</td>
<td>4.5</td>
<td>40.9</td>
<td>Male, castrated</td>
</tr>
<tr>
<td>Mixed breed</td>
<td>1</td>
<td>12.6</td>
<td>Male, castrated</td>
</tr>
<tr>
<td>Golden retriever</td>
<td>5.5</td>
<td>34.1</td>
<td>Male, intact</td>
</tr>
<tr>
<td>Mixed breed</td>
<td>1.5</td>
<td>34.1</td>
<td>Female, spayed</td>
</tr>
<tr>
<td>Miniature poodle</td>
<td>4.5</td>
<td>3.3</td>
<td>Male, castrated</td>
</tr>
<tr>
<td>Boston terrier</td>
<td>12.5</td>
<td>11.7</td>
<td>Female, spayed</td>
</tr>
<tr>
<td>Corgi</td>
<td>Unknown (adult)</td>
<td>12.8</td>
<td>Male, intact</td>
</tr>
<tr>
<td>Saint Bernard</td>
<td>1.5</td>
<td>55.0</td>
<td>Female, intact</td>
</tr>
<tr>
<td>Labrador retriever</td>
<td>4.5</td>
<td>23.3</td>
<td>Male, castrated</td>
</tr>
</tbody>
</table>

### TABLE 2. Proximate and Mineral Analysis of Diets

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Unit</th>
<th>Diet A*</th>
<th>Diet B†</th>
<th>Diet C‡</th>
<th>Diet D§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>% As fed</td>
<td>7.5</td>
<td>8.9</td>
<td>9.4</td>
<td>7.3</td>
</tr>
<tr>
<td>Crude protein</td>
<td>g/100 kcal ME</td>
<td>6.3</td>
<td>6.9</td>
<td>3.6</td>
<td>4.8</td>
</tr>
<tr>
<td>Crude fat</td>
<td>g/100 kcal ME</td>
<td>4.3</td>
<td>3.4</td>
<td>3.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>g/100 kcal ME</td>
<td>0.47</td>
<td>2.1</td>
<td>0.21</td>
<td>0.5</td>
</tr>
<tr>
<td>Calcium</td>
<td>g/100 kcal ME</td>
<td>0.26</td>
<td>0.33</td>
<td>0.17</td>
<td>0.14</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>g/100 kcal ME</td>
<td>0.20</td>
<td>0.25</td>
<td>0.07</td>
<td>0.11</td>
</tr>
<tr>
<td>Potassium</td>
<td>g/100 kcal ME</td>
<td>0.13</td>
<td>0.19</td>
<td>0.19</td>
<td>0.13</td>
</tr>
<tr>
<td>Sodium</td>
<td>g/100 kcal ME</td>
<td>0.10</td>
<td>0.09</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td>Nitrogen-free extract</td>
<td>g/100 kcal ME</td>
<td>9.9</td>
<td>13.0</td>
<td>14.3</td>
<td>11.1</td>
</tr>
<tr>
<td>ME</td>
<td>kcal/g of food</td>
<td>4.08</td>
<td>3.34</td>
<td>3.98</td>
<td>4.20</td>
</tr>
</tbody>
</table>

* Diet A = ProPlan Canine Chicken and Rice Adult (dry), Ralston Purina Co, St. Louis, MO, formulated between January 1 and July 1, 1996.
† Diet B = CNM Canine DCO (dry), Ralston Purina Co, St. Louis, MO, formulated between January 1 and July 1, 1996.
‡ Diet C = CNM Canine NF (dry), Ralston Purina Co, St. Louis, MO, formulated between January 1 and July 1, 1996.
§ Diet D = Prescription Diet Canine c/d (dry), Hill’s Pet Nutrition Inc, Topeka, KS, formulated between January 1 and July 1, 1996.

ME = metabolizable energy.
Experimental Design

In order to minimize differences attributable to individual dogs, a randomized block experiment was chosen to allow comparisons between diets consumed by the same dog. Dogs were randomly assigned to diet sequence.

Feeding Protocol

Each diet was fed for 21 days with the first 7 days used to gradually transition the dog onto the diet. For days 8 to 21 of each period, the test diet was fed exclusively. The amount of food was based on daily caloric requirements determined by body weight (132 kcal/d/kg\(^{0.75}\)); water was available at all times. On day 21, food but not water was withheld from dogs for 10 to 14 hours overnight and urine and blood were collected. Dogs were then fed one-half of their daily calculated requirements using the diet they had been consuming the previous 3 weeks. Urine was collected 4 and 8 hours later. Dogs were then transitioned onto the next diet in the sequence. Transition between diets was accomplished over 7 days by combining increasing amounts of new diet with decreasing amounts of old diet. Body weight was measured at the beginning and end of each feeding period.

Collection and Analysis of Blood and Urine Samples

Spontaneously voided urine samples were collected into sterile cups at 8 AM (after fasting), 12 PM (4 hours after eating), and 4 PM (8 hours after eating). A complete urinalysis was conducted on samples collected at 8 AM using dipstick semiquantitative analysis and by microscopic examination of sediment obtained after centrifugation of 5 mL of urine. Analysis results of urine samples for dipstick semiquantitative analyses of protein, glucose, ketones, bilirubin, and occult blood were graded using the following scale: negative = 0, trace = 1, small = 2, moderate = 3, large = 4. Analysis results for microscopic examination of sediment obtained after centrifugation were graded on the following scale: for red blood cells/high-power field (HPF), 0 = 0, <10 = 1, 10–50 = 2, 50–100 = 3, >100 = 4; for white blood cells/HPF, 0 = 0, <5 = 1, 5–10 = 2, 10–50 = 3, >50 = 4; and for epithelial cells/HPF, crystals/HPF, and bacteria/HPF, 0 = 0, few = 1, moderate = 2, and many = 3. Urinary pH was determined using a pH electrode. Urine from the sample collected at 8 AM was also submitted for aerobic bacteriologic culture. Blood samples for serum biochemical analysis and blood-ionized calcium concentrations were collected by jugular venipuncture. Serum was obtained by centrifugation of uncoagulated whole blood and analyzed for concentrations of urea nitrogen, creatinine, calcium, phosphorous, albumin, total protein, total bilirubin, sodium, potassium, chloride, and total carbon dioxide and activities of alanine aminotransferase and alkaline phosphatase using an automated chemistry analyzer. Blood-ionized calcium concentration was determined on 1 mL of heparinized whole blood using an automated analyzer.

STATISTICAL ANALYSIS

Data were analyzed using a microcomputer-based statistical software package on a desktop computer. Analysis of variance (ANOVA) was used to test the hypothesis that diet had no effect on mean results for each parameter measured by serum biochemical analysis and complete urinalysis. A repeated measure ANOVA was used to compare the effect of time after eating on urinary pH values. If ANOVA indicated that differences in a single variable could be attributed to diet consumed, comparisons between mean results of diet groups for that variable were conducted using Fisher’s protected least significant difference procedure. \( P < .05 \) was considered significant.
**RESULTS**

**Influence of Diet Sequence on Results**

The sequence of consuming diets did not have a significant effect on results. Significant differences in results obtained by serum biochemical analysis and urinalysis were not observed between treatment periods.\(^\text{12}\)

**Dogs**

Thirteen of 16 dogs completed the study, and results from only these dogs were used for analysis. One dog died from being hit by a car, one dog disappeared, and one dog would not eat Diet D. Body weight was held constant throughout the study for all dogs. Owners gave assurance that dogs consumed only study diets and that other feeds and treats were not given. Urine pH values were significantly higher when dogs consumed Diet C when compared with the other diets; there was no difference among the other 3 diets (Figure). The effect of time after eating was not significant. Differences were not observed in results obtained by complete urinalysis (Table 2). Bacteria were not observed in any urine sample, and all aerobic urine cultures were negative. Crystalluria was present in 23 of 52 urine samples evaluated: 5 of 13 samples from dogs when consuming Diet A, 4 of 13 samples from dogs when consuming Diet B, 9 of 13 samples from dogs when consuming Diet C, and 5 of 13 samples from dogs when consuming Diet D. In all but 2 samples, crystals were struvite or amorphous phosphate; calcium oxalate dihydrate crystals were observed in urine samples collected from 2 dogs when consuming Diet C. A positive reaction for bilirubin was observed in 27 of 42 samples; 19 samples from male dogs and 8 samples from female dogs (Table 3). Serum phosphorous concentrations were significantly lower when dogs consumed Diet C when compared with the other 3 diets. Differences in other serum biochemical variables were not found between diets (Table 4). All results for the parameters were within established reference ranges. Blood-ionized calcium concentrations were not different between diets (Table 4); all results were within established reference ranges.

**DISCUSSION**

Manipulation of urinary pH is important in certain types of urolith formation because urine acidity or alkalinity influences what type of mineral precipitates.\(^\text{1}\) Struvite is less soluble and therefore more likely to precipitate in alkaline urine. This has been evaluated in cats and is important in managing uroliths and plugs containing struvite.\(^\text{6}\) In most instances,
TABLE 3. Comparison of Results of Complete Urinalysis Obtained from 13 Dogs Fed 4 Different Diets After 10 to 12 Hours of Food Deprivation (Mean ± SD)*

<table>
<thead>
<tr>
<th></th>
<th>Diet A†</th>
<th>Diet B‡</th>
<th>Diet C**</th>
<th>Diet D††</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine specific gravity</td>
<td>1.037 ± 0.015</td>
<td>1.034 ± 0.015</td>
<td>1.030 ± 0.011</td>
<td>1.037 ± 0.014</td>
</tr>
<tr>
<td>Color</td>
<td>Yellow</td>
<td>Yellow</td>
<td>Yellow</td>
<td>Yellow</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Clear</td>
<td>Clear</td>
<td>Clear</td>
<td>Clear</td>
</tr>
<tr>
<td>Dipstick†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Ketones</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Protein</td>
<td>0.54 ± 1.20</td>
<td>0.31 ± 0.86</td>
<td>0.39 ± 0.96</td>
<td>0.54 ± 0.78</td>
</tr>
<tr>
<td>Bilirubin</td>
<td>1.00 ± 1.48</td>
<td>1.00 ± 1.23</td>
<td>1.23 ± 1.48</td>
<td>1.23 ± 1.24</td>
</tr>
<tr>
<td>Occult blood</td>
<td>0.15 ± 0.38</td>
<td>0.08 ± 0.28</td>
<td>0.15 ± 0.56</td>
<td>0.54 ± 1.13</td>
</tr>
<tr>
<td>Sediment examination</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RBC/HPF‡</td>
<td>0.77 ± 0.93</td>
<td>0.54 ± 0.52</td>
<td>0.69 ± 0.63</td>
<td>1.23 ± 0.93</td>
</tr>
<tr>
<td>WBC/HPF††</td>
<td>1.01 ± 0.76</td>
<td>0.92 ± 0.49</td>
<td>0.92 ± 0.76</td>
<td>1.08 ± 0.64</td>
</tr>
<tr>
<td>Bacteria/HPF‡‡</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Crystals/HPF‡‡</td>
<td>0.62 ± 1.12</td>
<td>0.31 ± 0.46</td>
<td>1.00 ± 1.00</td>
<td>0.69 ± 0.24</td>
</tr>
<tr>
<td>Epithelial cells/HPF‡‡</td>
<td>1.00 ± 1.00</td>
<td>0.77 ± 0.44</td>
<td>1.00 ± 0.71</td>
<td>1.08 ± 0.95</td>
</tr>
</tbody>
</table>

* Differences in results between diets were not found at the P<.05 levels.
† Scale used for results from dipstick: negative = 0; trace = 1; small = 2; moderate = 3; and large = 4.
‡ RBC/HPF: 0 = 0; <10 = 1; 10–50 = 2; 50–100 = 3; >100 = 4.
§ WBC/HPF: 0 = 0; <5 = 1; 5–10 = 2; 10–50 = 3; >50 = 4.
‡‡ Bacteria/HPF, crystals/HPF, and epithelial cells/HPF: 0 = 0; few = 1; moderate = 2; many = 3.
†† Diet A = ProPlan Canine Chicken and Rice Adult (dry), Ralston Purina Co, St. Louis, MO, formulated between January 1 and July 1, 1996.
‡ Diet B = CNM Canine DCO (dry), Ralston Purina Co, St. Louis, MO, formulated between January 1 and July 1, 1996.
** Diet C = CNM Canine NF (dry), Ralston Purina Co, St. Louis, MO, formulated between January 1 and July 1, 1996.
†† Diet D = Prescription Diet Canine c/d (dry), Hill’s Pet Nutrition Inc, Topeka, KS, formulated between January 1 and July 1, 1996.

struvite formation in cats occurs without a concomitant bacterial urinary tract infection. Dietary factors influence precipitation of sterile struvite uroliths in cats; the most important appears to be dietary influence on urinary pH. Therefore, many commercially available diets formulated for adult cats induce production of urine pH <6.8 in an effort to decrease risk of struvite formation in cats.

Struvite formation in dogs is most often associated with a bacterial urinary tract infection; however, there has been a report of sterile struvite urolith formation in three related English cocker spaniels. When urinary tract infections with urease-producing microbes occur in dogs, forming urine with a sufficient quantity of urea, concomitant elevations in ammonium and carbonate ions develop in an alkaline urine, favoring formation of uroliths containing struvite and calcium apatite. Dissolution of infection-induced struvite uroliths in dogs is induced by administering appropriate antimicrobial therapy and feeding a diet that, when compared with adult maintenance canine foods, contains lower quantities of protein, magnesium, phosphorous, an acidifying agent, and induces polyuria. Preventing infection-induced struvite uroliths in dogs depends on prevention or early treatment of bacterial urinary tract infec-
The role (if any) of diet is unknown. Because struvite is more soluble in acidic urine, promotion of urine pH <6.8 by dietary means appears logical. Little published data exists evaluating dietary influence on urinary pH in dogs.

In the study reported here, urinary pH was not significantly different among dogs fed Diets A, B, and D; however, it was significantly more alkaline when dogs consumed Diet C, which contained the lowest concentration of moisture, crude fiber, ash, chloride, magnesium, and phosphorous and the highest calculated nitrogen-free extract. As confirmed in this study, Diet C has been formulated to offset metabolic acidosis and produce alkaluria by addition of potassium citrate. Diet D is marketed to aid prevention of struvite urolith formation in dogs and contains added acidification; however, it did not induce a greater degree of aciduria, nor did it decrease crystalluria when compared with Diets A and B (adult canine maintenance diets). The rationale for feeding an acidifying diet to prevent infection-induced struvite uroliths in dogs is limited and not supported by this study.

Urine pH was measured before and after eating, and the postprandial alkaline tide was not obvious (Figure) or different than that observed in cats. These results differ from a study by Stevenson et al that demonstrated a postprandial alkaline tide when dogs were fed a canned diet with and without potassium citrate supplementation. In that study, a postprandial alkaline tide occurred between 1 and 5 hours after the morning meal. One possible explanation for the differences in results may be because of different formulations of diet fed (canned versus dry). Diets high in moisture are emptied from the stomach more quickly than dry diets; therefore, feeding a dry formulated diet may slow gastric emptying, resulting in a balance between gastric

TABLE 4. Comparison of Analyte Concentrations and Activities in Serum and Blood-Ionized Calcium Concentrations Obtained from 13 Dogs Consuming 4 Different Diets After 10 to 12 Hours of Food Deprivation (Mean ± SD)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Diet A*</th>
<th>Diet B†</th>
<th>Diet C‡</th>
<th>Diet D§</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood urea nitrogen (mg/dL)</td>
<td>18.2 ± 4.24</td>
<td>15.2 ± 5.72</td>
<td>13.2 ± 4.15</td>
<td>16.2 ± 3.76</td>
<td>.06</td>
</tr>
<tr>
<td>Creatinine (mg/dL)</td>
<td>1.17 ± 0.12</td>
<td>1.10 ± 0.14</td>
<td>1.07 ± 0.11</td>
<td>1.08 ± 0.14</td>
<td>.2</td>
</tr>
<tr>
<td>Calcium (mg/dL)</td>
<td>10.4 ± 0.93</td>
<td>10.3 ± 0.44</td>
<td>10.8 ± 0.44</td>
<td>10.7 ± 0.46</td>
<td>.14</td>
</tr>
<tr>
<td>Blood-ionized calcium (mM/L)</td>
<td>1.32 ± 0.05</td>
<td>1.31 ± 0.05</td>
<td>1.32 ± 0.08</td>
<td>1.32 ± 0.05</td>
<td>.88</td>
</tr>
<tr>
<td>Blood pH&lt;sub&gt;venous&lt;/sub&gt;</td>
<td>7.39 ± 0.03</td>
<td>7.39 ± 0.04</td>
<td>7.39 ± 0.02</td>
<td>7.38 ± 0.03</td>
<td>.54</td>
</tr>
<tr>
<td>Phosphorous (mg/dL)</td>
<td>4.07 ± 0.81&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.73 ± 0.65&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.31 ± 0.61&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.88 ± 0.63&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.04</td>
</tr>
<tr>
<td>Sodium (mEq/L)</td>
<td>153.8 ± 2.79</td>
<td>152.3 ± 1.80</td>
<td>153.3 ± 2.25</td>
<td>153.1 ± 1.50</td>
<td>.34</td>
</tr>
<tr>
<td>Potassium (mEq/L)</td>
<td>4.81 ± 0.27</td>
<td>4.75 ± 0.28</td>
<td>4.92 ± 0.45</td>
<td>4.72 ± 0.31</td>
<td>.42</td>
</tr>
<tr>
<td>Chloride (mEq/L)</td>
<td>121.6 ± 1.81</td>
<td>121.5 ± 2.07</td>
<td>121.2 ± 2.20</td>
<td>120.5 ± 2.18</td>
<td>.54</td>
</tr>
<tr>
<td>Total CO&lt;sub&gt;2&lt;/sub&gt; (mEq/L)</td>
<td>17.9 ±1.75</td>
<td>18.2 ± 3.03</td>
<td>19.0 ± 2.08</td>
<td>18.3 ± 1.89</td>
<td>.66</td>
</tr>
<tr>
<td>Anion Gap (mEq/L)</td>
<td>19.2 ± 1.09</td>
<td>17.4 ± 1.39</td>
<td>18.1 ± 2.56</td>
<td>19.0 ± 2.04</td>
<td>.05</td>
</tr>
</tbody>
</table>

*Diet A = ProPlan Canine Chicken and Rice Adult (dry), Ralston Purina Co, St. Louis, MO, formulated between January 1 and July 1, 1996.
†Diet B = CNM Canine DCO (dry), Ralston Purina Co, St. Louis, MO, formulated between January 1 and July 1, 1996.
‡Diet C = CNM Canine NF (dry), Ralston Purina Co, St. Louis, MO, formulated between January 1 and July 1, 1996.
§Diet D = Prescription Diet Canine c/d (dry), Hill's Pet Nutrition Inc, Topeka, KS, formulated between January 1 and July 1, 1996.
<sup>a</sup><sup>ab</sup><sup>b</sup>Values in rows with different superscripts refer to differences at the P <.05 levels.
secretion (high in acid) and pancreatic secretion (high in base). Whether feeding a canned diet or more frequent determination of urinary pH would have identified a postprandial alkaline tide is unknown.

Serum phosphorous concentrations were significantly lower for dogs that consumed Diet C when compared with dogs fed Diets A and D. Diet C contained less phosphorous than the other diets, which may explain this finding. No other differences in analyte concentrations or activities were found, and diet did not have a significant effect on urine specific gravity. Although bilirubinuria can be observed in clinically healthy male dogs, its presence in female dogs has been considered abnormal. In this study, bilirubinuria was present in eight samples collected from healthy female dogs; therefore, it does not necessarily represent a disease state.

Crystalluria was present in 44% of urine samples collected from the 13 dogs. Although struvite occurred in 21 of 23 samples, calcium oxalate crystals were observed in two samples collected from dogs when consuming Diet C. Crystalluria represents a normal physiologic process by which solid matter (minerals) may be eliminated in a liquid medium (urine). Results of this study demonstrate that struvite crystalluria is a common finding in healthy dogs. Observing calcium oxalate crystalluria was surprising. Reasons for calcium oxalate crystalluria in these samples are unknown but possible explanations include a dietary effect because they occurred in dogs consuming the same diet, a genetic predisposition of these two dogs for calcium oxalate crystalluria, or artificial formation from a temperature change of the urine. Although urine samples were analyzed within 15 minutes of collection, a temperature change from that in the body to that in the environment may result in spontaneous crystal formation.

One limitation of this study involved the use of commercially manufactured diets. The study was not designed to determine effect of any single nutrient or dietary component on urinary pH. Thus results were restricted and influenced by potential interactions among various dietary components and internal metabolic factors. Further studies on dietary influence of infection-induced struvite uroliths in dogs are desirable.

CONCLUSION

This study showed that influencing urinary pH of healthy dogs is possible. Most healthy dogs, except while consuming a diet specifically formulated to produce alkalinuria, produced urine with an acidic pH. These data do not support the need to feed a specifically formulated acidifying diet to prevent infection-induced struvite urolithiasis in dogs.

REFERENCES

7. Bartges JW, Osborne CA, Pozin DJ: Recurrent sterile


