Influence of the feed base excess on urine parameters in cats*

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Summary
In this study the base excess (BE) was used as a method to predict the influence of the food on the urinary pH on cats. Nine cat foods (six dry and three canned) were consecutively fed to eight cats. The urine pH, volume, specific gravity and water and food intake were determined daily. The base excess [BE; mmol/kg dry matter (DM)] was calculated from the compounds in the food (BE = 49.9*Ca+82.3*Mg*+43.5*-Na+25.6*K-64.6*P-13.4*Met-16.6*Cys-28.2*Cl). The BE of the tested foods was between −287.35 and 133.38 mmol/kg DM. The mean urine pH varied between 5.76 (SD = 0.13) and 7.16 (SD = 0.22). The BE correlated with the mean urine pH (pH = 6.25+0.0023*BE; r = 0.74**). The urine volume (ml/kg BW/day) correlated significantly positive with the K- (r = 0.71**) and significantly negative with the P-content (r = −0.67**), the Ca-content (r = −0.50**) followed by the Mg-content (r = −0.36**) of the food. The correlation coefficients between the anions/cations in the food and the urine pH was for K 0.36**, for P −0.61**, the Met+Cys −0.60** and Cl −0.27**. In practice the correlation between urine pH and BE would help to pre-estimate the effect of food on the urine pH and to prevent urolith formation.

Zusammenfassung
In dieser Studie wurde die Kalkulation des Basenexzesses (BE) als Methode verwendet, um den Einfluss des Futters auf den pH-Wert des Harns von Katzen festzustellen. Neun Katzenfutter (sechs Trocken- und drei Feuchtfutter) wurden an acht Katzen getestet. Der pH-Wert und das spezifische Gewicht des Harns sowie die Futter- und Wasseraufnahme wurden täglich bestimmt. Der Basenexzess (BE; mmol/kg Trockensubstanz (TS)) wurde aus den Inhaltsstoffen berechnet. (BE = 49.9*Ca+82.3*Mg*+43.5*-Na+25.6*K-64.6*P-13.4*Met-16.6*Cys-28.2*Cl). Von den getesteten Futtern wurde ein Basenexzess zwischen −287.35 TS und 133.38 mmol/kg TS errechnet. Der Harn pH-Wert schwankte zwischen 5.76 (SD = 0.13) und 7.16 (SD = 0.22). Der BE korrelierte mit dem durchschnittlichen Harn pH (pH = 6.25+0.0023*BE; r = 0.74**). Das Harnvolumen (ml/kg KM/Tag) korrelierte signifikant positiv mit dem K- (r = 0.71**) und signifikant negativ mit dem P-Gehalt (r = −0.67**), dem Ca-Gehalt (r = −0.50**) und Mg-Gehalt (r = −0.36**) im Futter. Korrelationskoeffizienten zwischen den Kationen/Anionen im Futter und dem pH-Wert Harn wurden für K 0.36**, für P −0.61**, für Met+Cys −0.519** und Cl −0.27**errechnet. Diese
Introduction

Urolithiasis in cats is the most common cause of feline lower urinary tract disease. A number of experimental studies have shown that urolithiasis can be induced in cats by dietary manipulation. Ingredients of diets and feeding patterns affect the volume, pH and specific gravity of the urine. Manipulation of urine pH through dietary means has proven an effective tool for the management and prevention of struvite urolithiasis (Markwell et al., 1998). Acidification of urine through dietary modification should prevent struvite urolithiasis in cats. A reduction of urine pH to approximately 6.0 induces dissolution of struvite uroliths (Taton et al., 1984; Buffington et al., 1985). On the other hand urinary acidification may be a risk factor for calcium oxalate urolithiasis (Kirk et al., 1995; Osborne et al., 1995). Cats with calcium oxalate urolithiasis typically have concentrated (mean pre-treatment urine specific gravity of around 1.040) and acid (urine pH of 6.3–6.7) urine (Osborne et al., 1994). Magnesium has been reported to be a calcium oxalate inhibitor in rats and humans (Osborne et al., 1986). For this reason orally added magnesium is recommended to prevent recurrence of calcium oxalate uroliths. The therapy of feline struvite uroliths often recommend restriction of magnesium and acidification of urine. The correlation of pH-Wert im Harn und Basenexzess kann bei der Vorausberechnung des Einflusses von Futtern auf den pH-Wert im Harn helfen und somit der Harnsteinbildung vorbeugen.

Animals, materials and methods

Animals

Eight, 2–4-year-old cats were allocated into metabolism cages (1 × 1 m, 3 m height). Cats were fed twice daily. Vaccinations and deworming procedures were performed. Food: Nine cat foods were fed (six dry and three canned foods; Masterfoods, Austria).

The base excess [BE; mmol/kg dry matter (DM)] can be calculated as follows from the compounds in the food (Kamphues et al., 2004). The mineral contents are filled in as g/kg DM.

\[
BE = 49.9 \cdot \text{Ca} + 82.3 \cdot \text{Mg}^+ + 43.5 \cdot \text{Na}^+ + 25.6 \cdot \text{K} - 64.6 \cdot \text{P} - 13.4 \cdot \text{Met} - 16.6 \cdot \text{Cys} - 28.2 \cdot \text{Cl}.
\]

Procedures

Urine was collected for 21 days (dry diet) or for 14 days (canned diet) respectively. The pH, volume and specific gravity of the urine as well as water and food intake were determined daily. The 24 h urine collection was done under a thin layer of thymol/mineral oil solution to prevent losses or pH changes by microbial activities and evaporation. At day 17 (dry food) and day 12 (canned food) a 48-hour frozen urine collection was done to determine the minerals, oxalate and ammonium content of the urine.

Analytical methods

Urine pH was measured using a digital pH metre (Beckman O 63, CA, USA) and the specific gravity (SG) was measured with a refractometer (A. Paar density meter DMA 35 N, Graz, Austria).

Frozen urine samples were analyzed at the Central Nutrition Laboratory; Pedigree Master Foods; Leistershire, GB. Minerals and ammonium content of the urine were measured by ion exchange chromatography.

Proximate analysis in feed was performed according to the procedures of Naumann and Bassler (1993). Calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K) and sodium (Na) were measured in food after wet ashing of the samples in a mixture of 40% HNO₃ (65%), 10% HCl (35%), 20% H₂O₂ (30%) and 30% water in a microwave oven (MLS GmbH.; MLS-Ethos plus, Leutkirch im Allgäu, Germany). Ca, Mg, Na and K were measured by atomic absorption spectrometry (Perkin Elmer 3030B, Wellesley, MA, USA), Phosphorus (P) by the
vanadate molybdate method using a spectrophotometer (Hitachi U 3000, Tokyo, Japan).

Statistics

Data are expressed as means and standard deviations (SD). The variables were evaluated using the Kolmogorov–Smirnov method in order to assess their normal distribution. Within the groups, all variables showed normal distribution. The differences between the groups were calculated with help of Scheffe procedure. The correlations (water intake, pH, amount of urine and BE) were measured using the Spearman method. The selected level of significance was p < 0.05 (*) and p < 0.01 (**).

Results

The mean body weight and the food and total water intake/kg BW/day are expressed in Table 1. The total water intake ranged between 25.9 ml/kg BW/day (SD = 5.9) when food 4 was fed and 51.20 (SD = 4.7) when food 7 was fed. The total water intake/kg BW/day correlated significantly positive with the K-content ($r = 0.84^{**}$) and the Mg-content ($r = 0.51^{**}$) of the food and with the Ca- and the P-content correlated the total water intake significantly negative ($r = -0.62^{**}$, $r = -0.70^{**}$). The total water intake and the urine volume correlated significantly ($r = 0.61^{**}$) positive. The intake of DM/kg BW per day ranged between 11.7 (SD = 1.4) when food 8 and 16.0 g (SD = 1.7) when food 7 was fed. The body weight was almost constant (4.01, SD = 0.8 and 4.38 kg SD = 0.9). Table 2 shows the content of P, Met, Cys and cations in the trial foods on DM basis.

The BE of the food as well as the volume, pH and specific gravity of the urine is listed in Table 3. The urine pH varied between 5.76 (SD = 0.13) when food 6 was fed and 7.16 (SD = 0.22). The correlation coefficients between the anions/cations in the food and the urine pH was for K 0.36**, for P −0.61**, the Met+Cys −0.60** and Cl −0.27**. The BE correlated with the mean urine pH (pH = 6.25+0.0023*BE; $r = 0.74^{**}$; Fig. 1). The differences between the mean pH values of the urine reflect the differences between the BE values. A negative correlation (p < 0.05) was calculated between the urine volume and the specific gravity, Ca, P, Mg, oxalate, ammonium and creatinine contents of the urine.

Table 1 Body weight (BW), Dry matter (DM) intake/kg BW/day and total water intake/kg BW/day

<table>
<thead>
<tr>
<th>Food</th>
<th>N</th>
<th>BW [kg]</th>
<th>DM intake/kg BW (calculated)</th>
<th>Total water intake/kg BW ml/day (calculated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>4.01 [0.81]</td>
<td>16.0 (1.7)</td>
<td>40.9^{bc} (5.4)</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>4.20 [0.98]</td>
<td>12.8 (2.8)</td>
<td>31.3^{ab} (8.2)</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>4.38 [1.09]</td>
<td>12.9 (3.2)</td>
<td>30.8^{ab} (9.1)</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>4.28 [0.82]</td>
<td>13.1 (2.6)</td>
<td>27.1^{a} (6.6)</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>4.09 [0.91]</td>
<td>12.9 (3.9)</td>
<td>28.4^{a} (8.3)</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
<td>4.08 [0.90]</td>
<td>12.6 (4.2)</td>
<td>31.1^{ab} (9.3)</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>4.35 [0.82]</td>
<td>13.7 (5.5)</td>
<td>52.1^{a} (4.7)</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>4.66 [0.95]</td>
<td>11.7 (1.4)</td>
<td>51.1^{cd} (5.3)</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>4.04 [0.84]</td>
<td>13.6 (3.4)</td>
<td>43.6^{cd} (9.8)</td>
</tr>
</tbody>
</table>

Values given are Mean (SD). The values with different superscripts (a, b, c, d) on the same raw are significantly different (p < 0.05).

Table 2 Dry matter (DM) and crude protein content (XP) and content of cations and anions in the trial food on DM basis

<table>
<thead>
<tr>
<th>Food</th>
<th>DM (%)</th>
<th>XP (%)</th>
<th>Ca [g/kg]</th>
<th>P [g/kg]</th>
<th>Mg [g/kg]</th>
<th>K [g/kg]</th>
<th>Na [g/kg]</th>
<th>Cl [g/kg]</th>
<th>Oxalate [g/kg]</th>
<th>Met [g/kg]</th>
<th>Cys [g/kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>93.00</td>
<td>36.02</td>
<td>9.46</td>
<td>9.13</td>
<td>0.77</td>
<td>10.10</td>
<td>10.75</td>
<td>20.54</td>
<td>0.24</td>
<td>7.53</td>
<td>5.05</td>
</tr>
<tr>
<td>2</td>
<td>92.60</td>
<td>38.98</td>
<td>10.91</td>
<td>10.04</td>
<td>0.86</td>
<td>8.23</td>
<td>11.23</td>
<td>18.36</td>
<td>0.32</td>
<td>9.07</td>
<td>5.51</td>
</tr>
<tr>
<td>3</td>
<td>92.60</td>
<td>35.64</td>
<td>9.88</td>
<td>7.86</td>
<td>0.81</td>
<td>8.98</td>
<td>13.07</td>
<td>23.76</td>
<td>0.36</td>
<td>8.32</td>
<td>5.08</td>
</tr>
<tr>
<td>4</td>
<td>92.30</td>
<td>34.09</td>
<td>12.77</td>
<td>9.59</td>
<td>0.76</td>
<td>8.10</td>
<td>7.56</td>
<td>13.64</td>
<td>0.28</td>
<td>8.01</td>
<td>5.09</td>
</tr>
<tr>
<td>5</td>
<td>93.60</td>
<td>33.33</td>
<td>11.32</td>
<td>10.35</td>
<td>1.18</td>
<td>8.45</td>
<td>10.41</td>
<td>15.06</td>
<td>0.54</td>
<td>3.95</td>
<td>2.88</td>
</tr>
<tr>
<td>6</td>
<td>93.20</td>
<td>34.44</td>
<td>8.56</td>
<td>10.39</td>
<td>0.64</td>
<td>8.88</td>
<td>10.32</td>
<td>20.82</td>
<td>0.45</td>
<td>6.97</td>
<td>5.58</td>
</tr>
<tr>
<td>7</td>
<td>22.60</td>
<td>43.04</td>
<td>6.65</td>
<td>6.07</td>
<td>0.61</td>
<td>13.79</td>
<td>10.58</td>
<td>18.75</td>
<td>0.15</td>
<td>6.25</td>
<td>4.46</td>
</tr>
<tr>
<td>8</td>
<td>20.60</td>
<td>38.35</td>
<td>9.76</td>
<td>7.43</td>
<td>0.68</td>
<td>15.29</td>
<td>11.89</td>
<td>24.27</td>
<td>0.12</td>
<td>6.80</td>
<td>3.88</td>
</tr>
<tr>
<td>9</td>
<td>25.10</td>
<td>35.06</td>
<td>7.01</td>
<td>5.82</td>
<td>0.57</td>
<td>11.16</td>
<td>8.21</td>
<td>17.93</td>
<td>0.53</td>
<td>6.77</td>
<td>4.38</td>
</tr>
</tbody>
</table>
The urine volume (ml/kg BW/day) correlated significantly positive with the K- \((r = 0.71**\)) and significantly negative with the P-content \((r = 0.67**\)), the Ca-content \((r = 0.50**\)) followed by the Mg-content \((r = 0.36**\)) of the food. The content of the minerals, oxalate, ammonium and creatinine in the cat’s urine is described in Table 4. The lowest mean specific gravity amounted to 1.026 (SD = 0.002) when food 8 (canned) was fed. When food 4 was given a high specific gravity of 1.058 (SD = 0.008) was determined.

### Discussion

The present investigation confirms, that the BE is a qualified method to predict the pH value in the urine. The results of this study agree with the results of Kienzle and Schuhknecht (1993). Their results showed a highly significant correlation between the BE in the food and the daily mean urine pH \((r = 0.99**\)). The BE in the study of Kienzle and Schuhknecht (1993) ranged between 598.6 and 163.0 mmol/kg DM \([BE = \frac{(pH-6.72)}{0.0021}\ mmol/kg\ DM, r = 0.90**\]). Our study showed a lower correlation coefficient of \(r = 0.74**, the BE ranged between 133.38 (food 5) and 287.35 (food 6), BE \(= \frac{(pH-6.25)}{0.0023}\ mmol/kg\ DM\). The reason that our correlation coefficient was not so high could be that the range was not so wide.

The mean urine pH of our foods was between 5.76 (SD = 0.13; food 6) and 7.16 SD = 0.22; food 7).
The pH of the urine in the study of Kienzle and Schuhknecht (1993) was among 6.36 and 7.89.

For struvite precipitates to form, the urine must be supersaturated with magnesium, ammonium and anionic phosphate. The correlation of the ammonium content and the pH of the urine \((r = -0.63**)\) is comparable but lower as in the study of Kienzle and Schuhknecht (1993), who found a coefficient of \(r = -0.74**\). The relation of these parameters also show that beside other parameters ammonium regulates the acid-base balance through the excretion by the kidney. Urinary pH influences the concentration of ammonium ions. Ammonia generated by urease enzyme provides necessary ions that react with available hydrogen ions to increase urinary pH. Foods that produce an acidic urine increase urinary ammonium concentration (Buffington et al., 1990). In our study the effect can also be seen. The highest ammonium concentration in the urine was measured when food 6 was fed. Ammonium concentration was 177.2 (SD = 23.0) and the pH was 5.76 (SD = 0.13). Food 7 was the other way around.

Varying dietary phosphorus levels can alter urinary phosphate concentrations in cats. The correlation coefficient of phosphorus intake and urinary excretion was \(r = -0.73**\). The concentration of anionic phosphate \((PO_4^{3-})\) is the important form, which is influenced by the pH. The results of this study showed a significant negative correlation \((r = -0.52**)\) between the pH and the phosphorus content in the urine. If the urine becomes more acidic, the anionic phosphate is converted to monobasic and dibasic phosphate. This reduces the availability of incorporation in struvite precipitates (Allen and Kruger, 2000).

The correlation between magnesium intake and excretion was also significant \((r = 0.66**)\). Foods recommended for prevention of struvite precipitation should meet the nutritional allowance for magnesium and avoid an excess. High magnesium contents are present in some commercial foods, because they contain ingredients high in magnesium, e.g., fish and poultry meal (Allen and Kruger, 2000). Food does not markedly influence the oxalate content in the urine. Oxalate intake and excretion showed a correlation of \(r = 0.24^*\). Oxalate is poorly absorbed from the intestinal tract. In people, only 5–15% of urinary oxalate is contributed by the diet. The remaining 85–95% are produced endogenously. The endogenous oxalate metabolism in cats is not well known.

The solute load of the food influences water consumption. The potassium, phosphor, chloride and sodium content of the food also correlated with the water intake. Foods with higher protein content are associated with higher water intake (Allen and Kruger, 2000). In this study, the crude protein intake of all foods correlated with the total water intake \((r = 0.55**)\) and only the six dry foods with the total water intake correlated \((r = 0.88**)\), but the crude protein content of the food did not correlate with the water intake.

**Conclusion**

As shown in many investigations before, the urine pH correlated with the BE of the food. In practice the correlation between food and BE helps to preestimate the effect of food on the urine pH and thus to prevent urolith formation.

**References**


