**Selected Gelling Agents in Canned Dog Food Affect Nutrient Digestibilities and Fecal Characteristics of Ileal Cannulated Dogs**

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**EXPANDED ABSTRACT**

**KEY WORDS:** dogs • canned dog food • gelling agents • digestibilities

Pet owners often feed their dogs a canned diet because of its increased palatability and digestibility, as well as perceived added enjoyment for the dog (1). Most canned dog diets contain a gelling agent (GA) that is generally a carbohydrate with several functional properties including gel formation upon processing (2). Although GAs improve the appearance of a canned diet, little is known of their effects on nutrient digestibilities. When GAs are fed as a powder, they have been shown to hinder absorption of fat in dogs (3) and glucose in humans (4). Torrsdottir et al. (5) found that, after canning, guar gum no longer impeded glucose absorption in humans. There are little published data available on the nutritional effects of GA. The objective of this study was to evaluate the effects of GA in a canned dog food on ileal and total gastrointestinal tract nutrient digestibilities and fecal characteristics of the dog.

**MATERIALS AND METHODS**

**Animals, diets and experimental design**

Six adult, purpose-bred female dogs with hound bloodlines were used. Dogs were ileal cannulated according to Walker et al. (6). Dogs averaged 25 kg in body weight. Dogs were housed individually in 1.2 m3 solid floor pens in a temperature-controlled room (21°C) at the animal care facility in the Edward R. Madigan Laboratory, University of Illinois. A 16-h light/8-h dark schedule was used. All dogs were allowed free access to water. The surgical and animal care procedures were approved by the University of Illinois Campus Laboratory Animal Care Advisory Committee before initiation of the experiment.

All dogs were fed canned diets consisting of chunks in gravy and containing different sources and levels of GA. The control diet contained no GA. Two levels (0.2 and 0.5% of the diet on a wet weight basis) of wheat starch, carrageenan and guar gum (1:1), and carrageenan and locust bean meal (LBM) (1:1) were used in this experiment. Diets were made at Rocofa B.V. (Ittervoort, The Netherlands). The chunk (or solid) portion of the diets was made in one batch. From this batch, 150 kg was taken to make each of the diets. For the diets that contained GA, the gravy was made separately and the GA was added to this fraction of the diet. After the addition of the gravy, the cans were sealed and sterilized.

Dogs were randomly assigned to diets in a 6 x 7 Youden square design with 9-d periods. During each period, d 1 through d 5 constituted the diet adaptation phase and d 6 through d 9 were the collection phase, during which fecal and ileal samples were collected. Dogs were given 1500 g/d of canned food on a wet weight basis with half offered at 0800 and 2000. Dogs were dosed with 0.5 g chromic oxide at each feeding as a digestibility marker.

**Sampling procedures and chemical analyses**

Ileal effluent was collected three times daily during the 4-d collection phase. Each ileal collection proceeded for 1 h. Ileal effluent was collected by attaching a Whirl-Pak bag (Nasco, Ft. Atkinson, WI) to the cannula barrel using a rubber band. Dogs wore Bite-Not collars (Bite-Not Products, San Francisco, CA) as needed during the collection to prevent them from removing the bags. Dogs were allowed to move freely during the collection. After each collection, ileal effluent samples were frozen at -20°C. At the end of the period, ileal samples were composited and weighed.

Feces were collected from the pen floor during the 4-d collection phase. Feces were scored and weighed at the time of collection. Scoring was determined as follows: 1 = hard, dry pellets: small, hard mass; 2 = hard, formed, dry stool: remains firm and soft; 3 = soft, formed moist: softer stool that retains shape; 4 = soft, unformed: stool assumes shape of container; and 5 = watery: liquid that can be poured. Feces were frozen at -20°C and then composited by dog at the end of each period.

All samples were freeze-dried and ground through a 2-mm mesh screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ) in preparation for chemical analyses.

Feed, ileal, fecal and food-refusal samples were analyzed for dry matter (DM) and ash concentrations according to AOAC (7). Chromium analysis was done on ileal and fecal samples by atomic absorption.
spectrophotometry (8). Crude protein (CP) was determined from Kjeldahl nitrogen values (7). Fat content was determined by acid hydrolysis (9) followed by ether extraction according to Babler (10). Gross energy was determined by use of a bomb calorimeter (Parr Instrument, Moline, IL; Parr Instrument Manuals). Ileal and feed samples were prepared for amino acid analyses using both acid hydrolysis (11) and oxidation methods (12). The amino acid concentrations then were determined using ion-exchange chromatography (13) on a GoldDV711 chromatograph (Beckman Instruments, Fullerton, CA). Diets were analyzed for total dietary fiber (TDF) according to Prosky et al. (14).

**Calculations and statistical analysis**

Dry matter flow (g/d) of ileal effluent and fecal DM output were calculated by dividing Cr intake (mg/d) by ileal or fecal Cr concentration (mg Cr/g sample). Nutrient flows were calculated by multiplying the DM flow by the concentration of the nutrient in the ileal or fecal DM. Ileal and total tract nutrient digestibilities were calculated by subtracting the nutrient flow (g/d) from the nutrient intake (g/d) and then dividing this value by nutrient intake (g/d).

Data were analyzed as a 6 × 7 Youden square by the general linear models procedure of SAS (SAS Institute, Cary, NC). The statistical model included the effects of animal, period and treatment. Treatments least-squares means were compared using preplanned orthogonal contrasts. Contrasts included: 1) control diet vs. all gelling agent-containing diets, 2) control diet vs. guar gum:carrageenan-containing diets, 3) control diet vs. LBM:carrageenan-containing diets, 4) control diet vs. starch-containing diets and 5) high gelling agent concentration vs. low gelling agent concentration.

**RESULTS AND DISCUSSION**

**Chemical composition**

The seven diets had similar concentrations of DM (19.2%), OM (89.5% DM), CP (33.7% DM), fat (25.4% DM), TDF (3.2% DM), gross energy (5.5 kcal/g DM) and total and most individual amino acids. This is to be expected, given that the only difference among diets was the GA added. One notable difference in amino acid composition among diets was the higher level of glycine (3.15%) and proline (2.49%) in the GA-containing diets compared to levels in the control (2.73 and 2.30%, respectively). This perhaps indicates a higher collagen concentration in the diets containing the GA. This was an unexpected result because collagen would come from the animal by-products found in the chunks of the canned diet. The chunks were made in one batch and subsamples were to have been taken from this batch to make the diets. However, these differences in glycine and proline concentrations would suggest a difference in the composition of the animal by-products used in the GA-containing diets.

**Apparent ileal digestibilities**

Ileal digestibilities are presented in Table 1. Ileal DM digestibility and ileal CP digestibility did not differ when comparing dogs fed diets containing GA to dogs fed the control diet. The CP digestibilities were similar to the values of Smeets-Peeters (15) when the same diets were tested in an in vitro model of the dog's gastrointestinal tract. In vitro ileal CP digestibilities ranged from 70.2% for the control to 75.8% for the diet containing 0.5% wheat starch (15). Dogs fed the diets containing GA also had higher ileal digestibilities of OM, fat and gross energy than dogs fed the control diet.

Addition of the GA may have influenced nutrient digestibilities at the ileum by increasing the viscosity of the intestinal digesta. In a dynamic in vitro model of canine digestion, digesta delivered to the ileocecal valve were more viscous for the diet with 0.5% guar/carrageenan (5.25 cP) than for the control (4.5 cP) (15). An increase in viscosity may have increased intestinal transit time, allowing a greater time of exposure of nutrients to digestive processes and leading to increased digestibilities.

**Table 1**

<table>
<thead>
<tr>
<th>Diet</th>
<th>Guar/carrageenan</th>
<th>LBM/carrageenan</th>
<th>Wheat starch</th>
<th>SEM</th>
<th>C vs. GA</th>
<th>C vs. Guar</th>
<th>C vs. LBM</th>
<th>C vs. Str</th>
<th>High vs. Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>Control</td>
<td>0.2%</td>
<td>0.5%</td>
<td>0.2%</td>
<td>0.5%</td>
<td>0.2%</td>
<td>0.5%</td>
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<tr>
<td></td>
<td>68.6</td>
<td>78.1</td>
<td>72.0</td>
<td>71.1</td>
<td>70.8</td>
<td>72.5</td>
<td>71.9</td>
<td>3.32</td>
<td>0.21</td>
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<td></td>
<td>Organic matter</td>
<td>76.6</td>
<td>84.6</td>
<td>80.4</td>
<td>79.5</td>
<td>81.4</td>
<td>80.9</td>
<td>2.30</td>
<td>0.05</td>
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<tr>
<td></td>
<td>Fat</td>
<td>85.5</td>
<td>97.7</td>
<td>97.0</td>
<td>96.6</td>
<td>97.7</td>
<td>97.3</td>
<td>0.41</td>
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<tr>
<td></td>
<td>Gross energy</td>
<td>80.0</td>
<td>87.6</td>
<td>83.9</td>
<td>82.9</td>
<td>85.2</td>
<td>84.3</td>
<td>1.92</td>
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<td></td>
<td>TEAA4</td>
<td>68.4</td>
<td>80.5</td>
<td>74.3</td>
<td>72.3</td>
<td>72.0</td>
<td>74.0</td>
<td>73.9</td>
<td>3.18</td>
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<td>TNEAA5</td>
<td>65.6</td>
<td>79.4</td>
<td>72.6</td>
<td>71.2</td>
<td>70.3</td>
<td>74.1</td>
<td>71.6</td>
<td>3.26</td>
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<td>TAA6</td>
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<td>79.8</td>
<td>73.6</td>
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<td>70.9</td>
<td>72.5</td>
<td>72.1</td>
<td>3.24</td>
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<tr>
<td>Fecal output (as is), g/g DM consumed</td>
<td>0.27</td>
<td>0.34</td>
<td>0.39</td>
<td>0.40</td>
<td>0.38</td>
<td>0.32</td>
<td>0.33</td>
<td>0.02</td>
<td>&lt;0.01</td>
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<tr>
<td>Fecal DM, %</td>
<td>32.7</td>
<td>36.2</td>
<td>35.6</td>
<td>35.7</td>
<td>34.8</td>
<td>37.8</td>
<td>35.8</td>
<td>1.20</td>
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<tr>
<td>Fecal score²</td>
<td>3.5</td>
<td>3.2</td>
<td>3.0</td>
<td>3.3</td>
<td>3.2</td>
<td>3.0</td>
<td>3.9</td>
<td>0.13</td>
<td>0.02</td>
</tr>
</tbody>
</table>

1 n = 42; SEM = pooled SEM.
2 LBM = locust bean meal.
3 Preplanned contrasts with P-value for each comparison: C vs. GA, control vs. gelling agent containing diets; C vs. Guar, control vs. guar-containing diets; C vs. LBM, control vs. LBM-containing diets; C vs. Str, control vs. starch-containing diets; H vs. L, high gelling agent level vs. low gelling agent level.
4 TEAA, total essential amino acids.
5 TNEAA, total nonessential amino acids.
6 TAA, total amino acids.
7 Scores based on the following scale: 1 = hard, dry pellets; 2 = hard, formed, dry stool that remains firm and soft; 3 = soft, formed, moist that retains shape; 4 = soft, unformed stool that assumes shape of container and is pudding-like; 5 = watery liquid that can be poured.
Apparent total tract digestibilities

Total tract DM digestibility was greater ($P < 0.01$) when dogs were fed the control diet than in dogs fed diets containing GA. No differences occurred in total tract OM, CP or fat digestibilities when comparing dogs fed the control diet to dogs fed the GA-containing diets. There may have been an increase in the microbial mass excreted in feces of dogs fed the GA-containing diets, which led to a higher fecal DM output. In an in vitro study that used fecal inoculum from female English pointers, total SCFA production was increased ($P < 0.05$) when guar gum (7.26 mmol/g of substrate OM) and LBM (5.81 mmol/g of substrate OM) were used as substrates. The increase in SCFA production would indicate an increase in microbial growth and activity (16).

Ileal amino acid digestibilities

Total amino acid (TAA) and total nonessential amino acid (TNEAA) digestibilities were lower when dogs were fed the control diet than when fed the GA-containing diets. Total essential amino acid (TEAA) digestibility tended to be lower when dogs fed the GA-containing diets. The increase in SCFA production would indicate an increase in microbial mass excreted in feces of dogs fed the GA-containing diets, which led to a higher fecal DM output. In an in vitro study that used fecal inoculum from female English pointers, total SCFA production was increased ($P < 0.05$) when guar gum (7.26 mmol/g of substrate OM) and LBM (5.81 mmol/g of substrate OM) were used as substrates. The increase in SCFA production would indicate an increase in microbial growth and activity (16).

Fecal characteristics

Because there was some variation among diets in DM intake, fecal output was calculated as g as-is feces excreted per g DM consumed. Dogs fed the control diet had lower fecal output (0.27 g as-is feces per g DM intake) than dogs fed GA (average, 0.36 g as-is feces per g DM intake across diets containing GA). The increase in fecal output is consistent with the fact that the diets with GA resulted in lower total tract DM digestibilities than those in the control diet. Diz et al. (18) fed Beagles guar gum, sugar-beet fiber and inulin mixed with homemade diets. All three diets significantly increased wet fecal output compared to that of a control diet with no supplemental fiber.

The fecal DM percentage was lower when dogs were fed the control diet (32.7%) compared to when dogs were fed diets containing GA (range 34.8 to 38.5%). Fecal scores ranged from 3.0 to 3.5. This range would suggest that feces of the dogs fed all diets were near the desired consistency. However, some differences existed among treatments. Dogs fed the control diet had higher fecal scores than those of dogs fed the diets with GA added. This is supported by the fact that dogs fed the control diet had the highest fecal moisture content.

Implications

The addition of GA had several desirable effects in this study. Diets containing GA resulted in higher digestibilities of some amino acids at the terminal ileum. The guar gum/carrageenan combination, in particular, increased the digestibility of most amino acids measured. The addition of GA also led to increased ileal OM, fat and gross energy digestibilities. However, there was one key negative effect of adding the GA. Fecal outputs, expressed on a g as-is output per g DM intake basis, were increased, although the fecal dry matter percentage was higher with the addition of gelling agents, implying a more desirable fecal consistency. It would appear that, based on the results of this study, the nutritional benefits of the addition of gelling agents to canned dog foods outweigh the detrimental aspects.

LITERATURE CITED