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# Apparent total tract energy and macronutrient digestibility and fecal fermentative end-product concentrations of domestic cats fed extruded, raw beef-based, and cooked beef-based diets

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**ABSTRACT:** The objectives of this study were to determine differences in apparent total tract energy and macronutrient digestibility, fecal and urine characteristics, and serum chemistry of domestic cats fed raw and cooked meat-based diets and extruded diet. Nine adult female domestic shorthair cats were utilized in a replicated 3 × 3 Latin square design. Dietary treatments included a high-protein extruded diet (EX; 57% CP), a raw beef-based diet (RB; 53% CP), and a cooked beef-based diet (CB; 52% CP). Cats were housed individually in metabolic cages and fed to maintain BW. The study consisted of three 21-d periods. Each period included diet adaptation during d 0 to 16; fecal and urine sample collections during d 17 to 20; and blood sample collection at d 21. Food intake was measured daily. Total feces and urine were collected for determination of nutrient digestibility. In addition, a fresh urine sample was collected from each cat for urinalysis, and a fresh fecal sample was collected from each cat for determination of DM percentage and ammonia, short-chain fatty acid (SCFA), and branched-chain fatty acid (BCFA) concentrations. All feces were scored after collection using a scale ranging from 1 (hard, dry pellets) to 5 (watery, liquid that can be poured). Blood was analyzed for serum metabolites. Apparent total tract DM, OM, CP, fat, and GE digestibilities were greater ($P \leq 0.05$) in cats fed RB and CB than those fed EX. Total fecal SCFA concentrations did not differ among dietary treatments; however, molar ratios of SCFA were modified by diet, with cats fed RB and CB having an increased ($P \leq 0.05$) proportion of fecal propionate and decreased ($P \leq 0.05$) proportion of fecal butyrate compared with cats fed EX. Fecal concentrations of ammonia, isobutyrate, valerate, isovalerate, and total BCFA were greater ($P \leq 0.05$) in cats fed EX compared with cats fed RB and CB. Our results indicated that cooking a raw meat diet does not alter apparent total tract energy and macronutrient digestibility and may also minimize risk of microbial contamination. Given the increasing popularity of feeding raw diets and the metabolic differences noted in this experiment, further research focused on the adequacy and safety of raw beef-based diets in domestic cats is justified.

**Key words:** cat, digestibility, extruded diet, fermentation end-product, raw and cooked meat-based diet



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## INTRODUCTION

Although raw meat has been traditionally fed to sled dogs and racing greyhounds (Chengappa et al., 1993; Hill, 1998; Morley et al., 2006), the feeding of unconventional diets, including those based on raw meat, has increased in show animals and pets (Freeman and Michel, 2001; CVM, 2004). Raw meat is a source of potentially pathogenic microorganisms (e.g., *Salmonella*, *Campylobacter* spp., and pathogenic strains of *Escherichia coli*) to the pet and handler. Few studies have examined human illness associated with pets (Morse et al., 1976; Sato et al., 2000); however, the presence of bacterial pathogens in raw meat diets has been well documented (Joffe and Schlesinger, 2002; Weese et al., 2005; Strohmeyer et al., 2006).

The FDA advises adequate heat treatment to most effectively reduce risk (CVM, 2004). The effectiveness of killing microbes in meat is affected by cooking method and length, and bacterial pathogen (Angelotti et al., 1961; Murphy et al., 2004).

The nutritional adequacy of raw and cooked meat diets for cats has not been adequately studied. The few studies performed with domestic and small exotic cats have reported greater nutrient digestibility of raw di-

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ets compared with extruded diets (Crissey et al., 1997; Vester et al., 2010a,b). Despite risk of bacterial contamination, no gastrointestinal distress was noted in these studies. The differences between raw or cooked meat-based and extruded diets in domestic cats have not been examined.

Thus, the objective of this study was to compare apparent total tract energy and macronutrient digestibility, fecal characteristics, and blood metabolite concentrations in domestic cats fed extruded, raw, and cooked diets. We hypothesized that total tract apparent energy and nutrient digestibilities of raw and cooked diets would be similar to each other, but greater than that of the extruded diet while maintaining normal fecal characteristics and blood metabolites.

## MATERIALS AND METHODS

All animal procedures were approved by the University of Illinois Institutional Animal Care and Use Committee before animal experimentation.

### *Experimental Design and Animals*

Nine healthy, intact adult female domestic shorthair cats (*Felis catus*; mean age = 1.51 ± 0.03 yr; mean BW = 3.12 ± 0.19 kg) were utilized in a replicated 3 × 3 Latin square design consisting of three 21-d periods. Each period included an adaptation phase (d 0 to 16), followed consecutively by a fecal and urine collection phase (d 17 to 20), and blood collection (d 21). Cats were housed individually in stainless-steel cages (0.61 × 0.61 × 0.61 m) at the University of Illinois in a temperature- (21°C) and light-controlled (14 h light:10 h dark) room. Water was provided ad libitum.

### *Diets*

Cats were randomly allotted to 1 of 3 dietary treatments at the beginning of the experiment: 1) a dry extruded diet (**EX**; Natura Pet Products Inc., Fremont, NE); 2) a raw beef-based diet (**RB**; Central Nebraska Packing Inc., North Platte, NE), or 3) a raw beef-based diet (Central Nebraska Packing Inc.) that had been cooked before feeding (**CB**). All diets were formulated to meet or exceed the nutrient requirements of domestic cats (NRC, 2006).

The raw beef-based diet, used for treatments 2 and 3, was stored frozen until 1 to 3 d before feeding, when it was thawed in a 4°C refrigerator. On the day of feeding, the raw beef-based diet for treatment 3 was cooked in a microwave for 45 to 60 s to an internal temperature of at least 71°C, which adheres to the safe food handling procedures recommended for ground beef by the USDA (2009), and then cooled to room temperature. To minimize microbial growth of the cooked and raw beef-based diets, cats were fed these treatments twice each day. The extruded diet was stored in a cool dry place until feeding.

Cats were fed to maintain their healthy adult BW. Body weight was measured twice weekly, and the amount of food offered was adjusted when BW had decreased or increased >0.05 kg. Food offered and refused was measured daily. Food refusals of beef-based diets were dried at 105°C to allow measurement of DMI.

### *Sample Collection*

Diet subsamples were collected and stored at −20°C. Subsamples were composited for each diet, lyophilized (Dry MP microprocessor-controlled freeze-dryer, FTS Systems, Stone Ridge, NY), and ground with dry ice through a 2-mm screen (Wiley mill model 4, Thomas Scientific, Swedesboro, NJ).

During the collection phase, total fecal and urinary outputs were collected. To ensure complete collection, cats were acclimated to a multi-tier litter box with no litter, which allowed urine flow to the bottom and feces to remain on the top. A freshly voided urine sample was obtained during the collection phase for complete urinalysis. The remaining urine was acidified immediately after urination with 10 mL of 2 *N* HCl to prevent loss of N. Acidified urine of individual cats was composited by period and stored at −20°C until further analysis.

Fresh fecal samples (within 15 min of defecation) were obtained during the collection phase. Fresh fecal pH was determined immediately after collection (Accumet 1001 pH meter, Fisher Scientific Inc., Pittsburgh, PA) equipped with a micro-combination pH electrode probe (MI-410, Microelectrodes Inc., Londonderry, NH). Fresh fecal samples were weighed and scored, and an aliquot was obtained. Aliquots of 3 to 4 g were immediately mixed with 5 mL of 2 *N* HCl to minimize loss of volatile components. The fresh fecal aliquot was stored at −20°C until further analysis. Total fecal output for each period was collected, composited, dried at 55°C, and ground through a 2-mm screen (Wiley Mill intermediate, Thomas Scientific).

On the final day of each period, 4 mL of blood was collected by jugular venipuncture. Before collection, cats were food-restricted overnight. Samples were immediately transferred to tubes (BD, Franklin Lakes, NJ) and stored on ice. All tubes were centrifuged within 1 h of collection at 1,100 to 1,300 × *g* for 15 min at 4°C. The supernatant was collected and stored at −80°C.

### *Chemical Analyses*

Diets and feces were analyzed for DM and OM according to AOAC (2006) and fat concentration by acid hydrolysis according to AACC (1983), followed by ether extraction according to Budde (1952). Dietary, fecal, and urinary GE were determined by bomb calorimeter (model 1261, Parr Instrument Co., Moline, IL). Dietary and fecal CP were determined accord-

ing to AOAC (2006; Leco Nitrogen/Protein Determinator model FP-2000, Leco Corporation, St. Joseph, MI). Diet samples were analyzed for total dietary fiber (**TDF**) according to Prosky et al. (1992). Before the TDF procedure, high fat (>15%) and very high fat (>30%) samples were incubated overnight, in 15 or 30 mL of 2:1 choloroform:methanol, respectively, and then filtered through 8 layers of Dacron. Because the diets were high in protein, water bath times were increased to 1 h, and amounts of Termamyl solution 120 L (0.2 mL) and protease P-5380 (0.5 mL) were greater than the standard assay. Serum metabolite concentrations were determined (Hitachi 911 clinical chemistry analyzer, Roche Diagnostics, Indianapolis, IN) by the University of Illinois Veterinary Diagnostic Laboratory.

After collection, all fecal samples were scored using the following scale: 1 = hard, dry pellets; 2 = dry, well-formed stools; 3 = soft, moist, formed stool; 4 = soft, unformed stool; and 5 = watery liquid that can be poured. Fresh fecal concentrations of ammonia, short-chain fatty acids (**SCFA**; acetate, propionate, and butyrate), and branched-chain fatty acids (**BCFA**; isovalerate, valerate, and isobutyrate) were determined from the acidified aliquot. Ammonia concentration was determined according to Chaney and Marbach (1962). Fecal SCFA and BCFA concentrations were determined by gas chromatography according to Erwin et al. (1961; Hewlett-Packard 5890A series II gas chromatograph, Palo Alto, CA) and a glass column (180 cm × 4 mm i.d.) packed with 10% SP-1200/1% $H_3PO_4$ on 80/100+ mesh Chromosorb WAW (Supelco Inc., Bellefonte, PA). Nitrogen was the carrier with a flow rate of 75 mL/min. Oven, detector, and injector temperatures were 125, 175, and 180°C, respectively.

### *Calculations*

Apparent total tract digestibility values were calculated using the following equation: [nutrient intake (g/d) − fecal output (g/d)/nutrient intake (g/d)] × 100. Dietary ME was calculated with data from individual cats utilizing the equation $ME_C$ = [GE intake (kcal/d) – fecal GE (kcal/d) – urinary GE (kcal/d)]/DMI (g/d). Additionally, to allow for comparison with the Association of American Feed Control Officials (**AAFCO**) estimation method that utilizes only dietary composition, we estimated dietary ME utilizing the equation $ME_{AAFCO}$ = 8.5 kcal/g of fat + 3.5 kcal/g of CP + 3.5 kcal/g of N-free extract (AAFCO, 2009).

### *Statistical Analysis*

All discrete data were analyzed using the Mixed Models procedure (SAS Inst. Inc., Cary, NC). The fixed effect of dietary treatment was tested. Cat and period were considered random effects. To examine the ME estimation method, the difference between $ME_C$ and $ME_{AAFCO}$ was determined and the least squares means for each diet were compared with zero. Fecal score data were compared using the GLIMMIX procedure of SAS. Least squares means were separated using LSD with a Tukey adjustment. A $P \leq 0.05$ was considered statistically significant.

**Table 1.** Chemical composition of the high-protein extruded (EX), raw beef-based (RB), and cooked beef-based (CB) diets (DM basis except for DM)[1,2]

| Item | EX | RB | CB |
|---|---|---|---|
| DM, % | 94.3 | 29.3 | 29.2 |
| OM, % | 89.9 | 92.2 | 92.1 |
| CP, % | 57.0 | 52.5 | 52.0 |
| Acid hydrolyzed fat, % | 17.4 | 20.5 | 18.3 |
| Total dietary fiber, % | 4.2 | 4.2 | 4.9 |
| GE, kcal/g | 5.6 | 6.0 | 6.0 |
| $ME_{AAFCO}$,[3] kcal/g | 3.9[a] | 4.1[a] | 4.0[a] |
| $ME_C$,[4] kcal/g | 4.2[b] | 5.0[b] | 4.7[b] |

[a,b]$ME_C$ and $ME_{AAFCO}$ within the same diet differ ($P \leq 0.05$).

[1]Dietary composition was determined by analyzing subsamples collected and composited throughout the experiment. Accuracy was ensured by adequate replication with acceptance of mean values that were within 5% of each other.

[2]Ingredients for EX (Natura Pet Products Inc., Fremont, NE): chicken meal, potato product, chicken fat, dried egg, herring meal, beet pulp, natural flavors, herring oil, premium cat vitamin premix, salt, premium cat mineral mix, potassium chloride, dried chicory root, dried natural antioxidant, DL-Met; and ingredients for RB and CB (Central Nebraska Packing Inc., North Platte, NE): beef, meat by-products, fish meal, soybean meal, dried beet pulp, calcium carbonate, dried egg, brewers dried yeast, feline vitamin premix (vitamin A acetate, thiamine mononitrate, D-calcium pantothenate, mineral oil, D-biotin, pyridoxine hydrochloride, vitamin $D_3$ supplement), taurine, trace mineral premix (zinc oxide, manganous oxide, copper oxide, mineral oil, sodium selenite, calcium iodate). Diets were formulated to meet the nutrient requirements of the domestic cat (NRC, 2006).

[3]$ME_{AFFCO}$ = 8.5 kcal of ME/g of fat + 3.5 kcal of ME/g of CP + 3.5 kcal of ME/g of N-free extract.

[4]$ME_C$ = [GE intake (kcal/d) – fecal GE (kcal/d) – urinary GE (kcal/d)]/DMI (g/d).

## RESULTS

Dietary ingredient and chemical composition are presented in Table 1. Because of differences in ingredient composition between the extruded diet and raw and cooked beef-based diets, the effects of dietary composition and extrusion cannot be separated. For EX, RB, and CB, the difference between $ME_{AAFCO}$ and the $ME_C$ was greater ($P \leq 0.05$) than zero.

The final average BW (3.20 ± 0.20 kg) was maintained within 5% of starting BW and was not affected by dietary treatment. Food intake (g of DM/d and kcal/d) was greater ($P \leq 0.05$) in cats fed EX compared with cats fed RB and CB, and in cats fed RB compared with those fed CB (Table 2). Fecal output, on a DM or an as-is basis, and the ratio of fecal output (g as-is)/food intake (g of DM) were greater ($P \leq 0.05$) in cats fed EX compared with those fed RB and CB.

Apparent total tract DM, OM, CP, fat, and GE digestibilities were greater ($P \leq 0.05$) when cats consumed RB and CB compared with cats fed EX (Table

**Table 2.** Food intake, fecal output, apparent total tract macronutrient digestibility, and urine characteristics of domestic cats (n = 9) fed a high-protein extruded (EX), raw beef-based (RB), or cooked beef-based (CB) diet[1]

| Item | EX | RB | CB | SEM | *P*-value |
|---|---|---|---|---|---|
| Intake | | | | | |
| Food intake, g of DM/d | 56.6[c] | 49.5[b] | 42.1[a] | 2.8 | 0.005 |
| Caloric intake, kcal/d | 315.4[c] | 295.9[b] | 253.4[a] | 16.4 | 0.037 |
| Fecal output | | | | | |
| Fecal output, g as-is/d | 36.1[b] | 17.6[a] | 17.4[a] | 3.3 | <0.001 |
| Fecal output, g of DM/d | 13.0[b] | 6.7[a] | 7.2[a] | 0.6 | <0.001 |
| Fecal output (g as-is)/intake (g of DM) | 0.6[b] | 0.4[a] | 0.5[a] | 0.0 | <0.001 |
| Apparent digestibility, % | | | | | |
| DM | 78.2[a] | 86.7[b] | 83.8[b] | 1.7 | <0.001 |
| OM | 83.9[a] | 90.5[b] | 88.5[b] | 1.3 | <0.001 |
| CP | 81.6[a] | 93.3[b] | 92.9[b] | 1.2 | <0.001 |
| Fat | 91.3[a] | 95.5[b] | 95.3[b] | 0.4 | <0.001 |
| Energy | 84.7[a] | 91.5[b] | 89.8[b] | 1.1 | <0.001 |
| Urine | | | | | |
| Volume, mL/d | 53.4 | 54.5 | 59.5 | 7.2 | 0.815 |
| Specific gravity | 1.064 | 1.065 | 1.067 | 0.004 | 0.887 |

[a–c]Within a row, means lacking a common superscript differ ($P \leq 0.05$).

[1]Diets: EX, Natura Pet Products Inc. (Fremont, NE); and RB and CB, Central Nebraska Packing Inc. (North Platte, NE).

2.). Urine volume and specific gravity did not differ among dietary treatments.

Fecal DM percentage did not differ among dietary treatments (Table 3). Fecal scores and ammonia concentrations for cats fed EX were greater ($P \leq 0.05$) compared with cats fed RB and CB. Fecal propionate concentrations in cats fed CB were greater ($P \leq 0.05$) compared with cats fed EX. Fecal butyrate concentrations in cats fed EX were greater ($P \leq 0.05$) compared with cats fed CB and RB. Total fecal SCFA concentrations did not differ among dietary treatments; however, molar ratios of SCFA were modified by diet. The proportion of fecal propionate was greater ($P \leq 0.05$) in cats fed RB (23.6%) and CB (25.5%) compared with cats fed EX (17.8%). Conversely, the proportion of fecal butyrate was decreased ($P \leq 0.05$) in cats fed RB (7.6%) and CB (5.9%) compared with those fed EX (11.4%). Fecal concentrations of isobutyrate, valerate, isovalerate, and total BCFA were greater ($P \leq 0.05$) in cats fed EX compared with cats fed RB and CB.

Dietary treatment affected food-restricted serum concentrations of creatinine and triglycerides (Table 4). Serum creatinine concentration was greater ($P \leq 0.05$) in cats fed RB and CB compared with cats fed EX. Serum triglyceride concentration was greater ($P \leq 0.05$) in cats fed CB compared with cats fed EX. Despite statistical differences, serum creatinine and triglycerides were considered normal for all treatments. All other

**Table 3.** Stool quality and ammonia, short-chain fatty acid (SCFA), and branched-chain fatty acid (BCFA) concentrations (μmol/g of DM) of domestic cats (n = 9) fed a high-protein extruded (EX), raw beef-based (RB), or cooked beef-based (CB) diet[1]

| Item | EX | RB | CB | SEM | *P*-value |
|---|---|---|---|---|---|
| Fecal DM, % | 38.9 | 38.5 | 41.1 | 2.8 | 0.559 |
| Fecal score[2] | 3.3[b] | 2.9[a] | 2.8[a] | 0.2 | 0.003 |
| Ammonia | 190.4[b] | 69.4[a] | 72.0[a] | 17.9 | <0.001 |
| Acetate | 214.6 | 178.2 | 275.3 | 48.9 | 0.231 |
| Propionate | 50.9[a] | 65.3[ab] | 102.7[b] | 16.6 | 0.003 |
| Butyrate | 38.2[b] | 21.2[a] | 25.5[a] | 3.2 | 0.031 |
| Total SCFA[3] | 305.1 | 266.3 | 404.7 | 66.9 | 0.199 |
| Isobutyrate | 10.1[b] | 4.9[a] | 5.1[a] | 0.9 | <0.001 |
| Valerate | 18.3[b] | 6.0[a] | 5.3[a] | 1.9 | <0.001 |
| Isovalerate | 15.3[b] | 6.7[a] | 6.4[a] | 1.3 | <0.001 |
| Total BCFA[4] | 43.7[b] | 17.6[a] | 16.8[a] | 3.5 | <0.001 |

[a,b]Within a row, means lacking a common superscript differ ($P \leq 0.05$).

[1]Diets: EX, Natura Pet Products Inc. (Fremont, NE); and RB and CB, Central Nebraska Packing Inc. (North Platte, NE).

[2]Fecal scores based on the following scale: 1 = hard, dry pellets; 2 = dry, well-formed stools; 3 = soft, moist, formed stool; 4 = soft, unformed stool; and 5 = watery, liquid that can be poured.

[3]Total SCFA = acetate + propionate + butyrate.

[4]Total BCFA = isobutyrate + valerate + isovalerate.

**Table 4.** Food-restricted blood metabolite concentrations of domestic cats (n = 9) fed a high-protein extruded (EX), raw beef-based (RB), or cooked beef-based (CB) diet[1]

| Item | EX | RB | CB | SEM | *P*-value | Reference range[2] |
|---|---|---|---|---|---|---|
| Urea N, mg/dL | 29.9 | 27.4 | 28.7 | 1.3 | 0.428 | 15.4 to 31.2 |
| Total protein, g/dL | 7.0 | 7.2 | 7.2 | 0.2 | 0.373 | 5.7 to 8.0 |
| Albumin, g/dL | 4.0 | 4.0 | 4.1 | 0.2 | 0.750 | 2.4 to 3.7 |
| Calcium, mg/dL | 10.7 | 11.0 | 10.9 | 0.2 | 0.119 | 7.9 to 10.9 |
| Phosphorus, mg/dL | 4.7 | 5.0 | 5.2 | 0.2 | 0.133 | 4.0 to 7.3 |
| Sodium, mmol/L | 151.8 | 153.2 | 152.2 | 0.7 | 0.264 | 140.3 to 153.9 |
| Potassium, mmol/L | 4.3 | 4.5 | 4.5 | 0.2 | 0.180 | 3.8 to 5.3 |
| Chloride, mmol/L | 117.5 | 116.8 | 115.5 | 0.8 | 0.123 | 107.5 to 129.6 |
| Glucose, mg/dL | 72.6 | 80.4 | 81.6 | 6.0 | 0.152 | 60.8 to 124.2 |
| ALT,[3] U/L | 57.0 | 67.8 | 70.1 | 6.8 | 0.083 | 8.3 to 52.5 |
| Cholesterol, mg/dL | 154.9 | 176.7 | 165.3 | 13.0 | 0.180 | 71.3 to 161.2 |
| Bicarbonate, mmol/L | 17.5 | 18.4 | 17.4 | 0.9 | 0.547 | 16.4 to 22.0 |
| Creatinine, mg/dL | 1.2[a] | 1.5[b] | 1.5[b] | 0.1 | 0.019 | 0.5 to 1.9 |
| NEFA, mEq/L | 0.5 | 0.5 | 0.5 | 0.1 | 0.943 | NA[4] |
| Triglycerides, mg/dL | 26.7[a] | 32.4[ab] | 37.3[b] | 1.9 | 0.004 | 8.9 to 71.2[5] |

[a,b]Within a row, means lacking a common superscript differ ($P \leq 0.05$).

[1]Diets: EX, Natura Pet Products Inc. (Fremont, NE); and RB and CB, Central Nebraska Packing Inc. (North Platte, NE).

[2]Merck (2005).

[3]ALT = alanine aminotransferase.

[4]NA = not available.

[5]Kluger et al. (2009).

serum metabolites did not differ among dietary treatments.

## DISCUSSION

Feeding commercially prepared, raw meat-based diets to captive exotic felids is common in zoological parks, and the use of raw meat diets in the home for domestic cats is growing. However, there are few peer-reviewed trials that have examined the digestibility of raw meat-based diets in exotic (Crissey et al., 2001; Vester et al., 2008, 2010a,b) or domestic felids (Vester et al., 2010a). Moreover, exposure to raw meat increases the risk of bacterial contamination and illness to humans and animals (Joffe and Schlesinger, 2002; Stiver et al., 2003; Morley et al., 2006). Ways to decrease risk of bacterial contamination include feeding a commercially available, nutritionally complete extruded diet or cooking the diets. Although Vester et al. (2010b) compared a commercially available extruded diet and a raw beef-based diet in African wildcats, as far as we know, a comparison of these diet types has not been performed in domestic cats until now.

### *Dietary Composition*

The diets studied herein were representative of commercially available diets. Because the ingredient composition of EX was different than that of RB and CB, we acknowledge that the influence of the dietary composition and extrusion cannot be separated. Because CB was the same diet as RB in terms of the ingredient composition, the effects can be attributable only to the cooking process.

### *ME*

Metabolizable energy can be estimated from nutrient composition of the diet using predictive equations. Because interactions among nutrients and effects of processing are not considered, the estimations are limited. Additionally, precision is lost when digestibility of the diets to which the equation is applied is different from the digestibility of the diets used to obtain the equation. The model regulations of the AAFCO recommend utilizing the modified Atwater's values of 8.5, 3.5, and 3.5 kcal of ME/g for fat, protein, and NFE, respectively, to estimate ME of cat foods (AAFCO, 2009). Metabolizable energy was underestimated for all diets using the strategy of AAFCO ($ME_{AAFCO}$). This indicates that greater values may be necessary for extruded and raw meat-based diets with similar digestibilities (i.e., 89 to 93% OM digestibility) as those fed in this experiment.

### *Apparent Total Tract Energy and Macronutrient Digestibility*

All diets tested in this experiment were highly digestible. Diet influenced apparent total tract macronutrient digestibilities, which may have been due to differences in ingredient composition, macronutrient composition, or processing procedures of the diets. Apparent total tract macronutrient digestibility values in cats fed EX were within ranges reported in recent literature (Fekete et al., 2004, 2005; de-Oliveira et al., 2008; Prola et al., 2010). The raw and cooked beef-based diets tested in this study had similar macronutrient digestibilities. The authors are unaware of any experiments that have

determined the digestibility of a cooked meat-based diet in domestic cats. Vester et al. (2010a) fed domestic cats raw beef diets with an ingredient composition similar to those fed in this study; however, macronutrient composition differed. Dietary CP in that study was 5 to 6% units greater and fat was 6 to 8% units greater than that of the RB fed in this study. Apparent total tract DM, CP, fat, and GE digestibilities were similar across studies, but OM digestibility in this study was 5% units less than in that reported by Vester et al. (2010a). This difference could be due to differences in macronutrient composition (i.e., CP and fat). Percentage of TDF could also have influenced the results; however, Vester et al. (2010a) did not report dietary fiber.

The differences in digestibility observed between cats fed EX and RB were similar to previous studies in African wildcats (Vester et al., 2010b) and sand cats (*Felis margarita*; Crissey et al., 1997). In Vester et al. (2010b), diets fed to African wildcats had an identical ingredient composition and similar chemical composition [high-protein extruded diet (DM: 94%, CP: 52.9%, and fat: 23.5%); raw beef-based diet (DM: 38.2%, CP: 44.9%, and fat: 36.9%)] to those fed in the current study. Apparent total tract CP digestibility was greater in African wildcats fed raw beef-based diets (91.7%) compared with cats fed the extruded diet (84.1%). Similarly, we observed a 12% unit decrease in CP digestibility in cats fed EX compared with cats fed RB; however, we also noted decreased apparent total tract DM (9% unit), OM (7% unit), fat (4.2% unit), and GE (6.8% unit) digestibilities in cats fed EX. This discrepancy could be due to a larger sample size used in our study (n = 9 vs. 4). Despite the statistical differences, our apparent total tract DM, OM, fat, and GE digestibilities in domestic cats fed RB were almost identical to those reported by Vester et al. (2010b), whereas digestibility values in domestic cats fed EX were 3 to 4% units less than those reported for African wildcats. This indicates that our EX diet may have been less digestible than the extruded diet fed by Vester et al. (2010b), despite having similar formulation.

Crissey et al. (1997) observed numerical differences in apparent total tract digestibility between sand cats fed a chicken and soy-based extruded diet (DM, 94% and CP, 40.2%) and a raw horse meat-based diet (DM, 32% and CP, 57.2%). Dry matter, CP, and GE digestibilities were 11, 14, and 13% units greater, respectively, in sand cats fed the raw-meat based diet than sand cats fed the extruded diet. In the current study, smaller digestibility differences were observed when comparing cats fed raw and extruded diets. Apparent total tract DM, CP, and GE digestibilities of each diet type from the current study were greater than those reported in sand cats, and the magnitude of the difference was greater in extruded diets (5% units greater) than raw-meat diets (3% units greater). Differences observed between studies also could be due to differences in ingredient and macronutrient composition of diets tested.

### *Fecal Characteristics and Fermentative End-Products*

The greater fecal output (g/d, as-is and DM) in cats fed EX may be explained by the greater food intake to maintain BW and lower digestibility of the diet. Greater TDF in the EX diet may have played a role. Although cats fed EX had greater fecal scores (looser stools) compared with cats fed RB and CB, all fecal scores were close to the ideal score (3 out of 5). Fecal scores in cats in the current study were, again, greater and closer to the ideal score than those reported by Vester et al. (2010b) in African wildcats fed similar diets.

Fecal SCFA and BCFA concentrations were similar to values for domestic cats reported in the literature (Hesta et al., 2001; Vester et al., 2010a). Feces of cats fed EX had a greater ratio of butyrate and a decreased ratio of propionate compared with cats fed RB and CB diets. This indicates that carbohydrate fermentation in the hindgut may have been modified by diet. However, because absorption of SCFA was not measured and may be variable, their fecal concentrations are difficult to interpret. The inclusion of chicory root, a source of inulin, in the EX diet may have contributed to these results. Hesta et al. (2001) reported a decrease in ratio of fecal acetate:propionate when cats were fed diets containing 3 or 6% inulin. An increase in the butyrate proportion of fecal SCFA, similar to that in this experiment, was observed in African wildcats fed a high-protein extruded diet compared with those fed RB (Vester et al., 2010b). However, Vester et al. (2010b) reported no other dietary related differences in fecal SCFA and BCFA concentrations.

Ammonia and BCFA are putrefactive compounds produced during colonic fermentation of endogenous and nonabsorbed, dietary AA. Fecal ammonia and BCFA concentrations were greater in cats fed EX. The decreased digestibility of CP in cats fed EX was likely the reason for differences noted herein. Fecal ammonia concentration was similar for cats in the current study and African wildcats reported by Vester et al. (2010b) fed high protein, but were 64% less in our cats vs. African wildcats fed RB.

### *Blood Metabolites*

Serum creatinine and triglyceride concentrations were altered by diet, but those were within reference ranges. Serum albumin concentrations were greater than feline reference values (Merck, 2005). Serum albumin is a major determinant of osmotic pressure in the blood and is affected by dietary and metabolic influences. Hypoalbuminemia, in conjunction with other abnormal values, can be used in many diagnoses, including malnutrition and liver damage. Increased serum albumin concentrations have been associated with intake of high-protein [>2 g/(kg·d) diets and dehydration in humans (Mutlu et al., 2006)]. The high protein (52 to 57%) content of

diets fed in the current experiment likely contributed to the increased serum albumin concentrations observed. Serum albumin concentrations were similar to those reported by Vester et al. (2009) in kittens fed a high-protein (53% CP) extruded diet. In that study, albumin concentrations were increased from 3.6 g/dL in cats fed a high-carbohydrate (34% CP) extruded diet to 4.0 g/dL in cats fed the high-protein (53% CP) extruded diet. Cats had free access to water at all times; however, water intake was not measured and could have influenced albumin levels.

### *Summary and Conclusions*

Although the raw and cooked beef-based diets were more digestible than EX, all diets were highly digestible in this experiment. All cats maintained BW throughout the study. Few differences in serum metabolites were detected when cats were fed EX compared with RB and CB. Urine variables did not differ among diets. All scores of fecal consistency were within a desirable range, but cats fed EX had greater scores (looser stools) compared with cats fed RB and CB. Similarities in fecal SCFA concentrations indicate that carbohydrate fermentation was similar for all diets. Fecal putrefactive compounds, namely ammonia and BCFA, were increased in cats fed EX, but were similar to values reported in the literature for healthy cats. Given the increasing popularity of feeding raw diets, and differences among cats in metabolism of raw and extruded diets in this experiment, further research focused on the adequacy and safety of raw beef-based diets in domestic cats is justified. Because cooking may minimize risk of microbial contamination, and the results from the cooked beef-based diet tested herein were not different than the raw diet, cooking may be an appropriate modification to this feeding strategy. However, further evaluation of raw and cooked meat-based diets for domestic cats is warranted.

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