Fiber is a complex and varied group of compounds classified together on the basis of common indigestibility by the enzymes of the mammalian digestive tract. Many of these are complex carbohydrates such as cellulose and hemicelluloses that are composed of sugar molecules joined by β-linkages. Lignin, phytochemicals, and waxes are not composed of sugars but are similarly indigestible and are also considered fiber. Cellulose, hemicelluloses, and lignin are considered IDF, whereas pectins, plant gums, and oligosaccharides (chicory or purified inulin, fructooligosaccharide, galactooligosaccharide, and mannan-oligosaccharide) are considered SDF. Most SDF is fermentable by bacteria present in the mammalian intestinal tract. This fermentative process provides potential intestinal health benefits because the short-chain fatty acid end-products are used as an energy source by colonocytes and may be used systemically for gluconeogenesis.

### Objective
To assess differences among reported maximum crude fiber (CF), measured CF, and measured total dietary fiber (TDF) concentrations, and determine fiber composition in dry and canned nontherapeutic diets formulated for adult maintenance or all life stages of dogs.

### Design
Prospective cross-sectional study.

### Sample
Dry (n = 20) and canned (20) nontherapeutic canine diets.

### Procedures
Reported maximum CF concentrations were obtained from product labels. Concentrations of CF and TDF were measured in samples of the diets for comparison. For each diet, percentages of TDF represented by insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) were determined.

### Results
For dry or canned diets, the median reported maximum CF concentration was significantly greater than the median measured value. Measured CF concentration was significantly lower than measured TDF concentration for all diets. Median percentage of TDF (dry-matter basis) in dry and canned diets was 10.3% and 6.5%, respectively (overall range, 3.9% to 25.8%). Fiber composition in dry and canned diets differed; median percentage of TDF provided by IDF (dry-matter basis) was 83.4% in dry diets and 63.6% in canned diets.

### Conclusions and Clinical Relevance
Among the evaluated diets, measured CF concentration underrepresented measured TDF concentration. Diets provided a wide range of TDF concentration, and proportions of IDF and SDF were variable. In the absence of information regarding TDF concentration, neither reported maximum nor measured CF concentration appears to be a particularly reliable indicator of fiber concentration and composition of a given canine diet. (J Am Vet Med Assoc 2013;242:936–940)

### Abbreviations

<table>
<thead>
<tr>
<th>AOAC</th>
<th>Association of Analytical Communities</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>Crude fiber</td>
</tr>
<tr>
<td>GA</td>
<td>Guaranteed analysis</td>
</tr>
<tr>
<td>IDF</td>
<td>Insoluble dietary fiber</td>
</tr>
<tr>
<td>ME</td>
<td>Metabolizable energy</td>
</tr>
<tr>
<td>NFE</td>
<td>Nitrogen-free extract</td>
</tr>
<tr>
<td>SDF</td>
<td>Soluble dietary fiber</td>
</tr>
<tr>
<td>TA</td>
<td>Typical analysis</td>
</tr>
<tr>
<td>TDF</td>
<td>Total dietary fiber</td>
</tr>
</tbody>
</table>

In the United States, Association of American Feed Control Officials guidelines require pet food product labels to display the food’s maximum concentration of CF on an as-fed basis, although a more accurate CF value (included in a TA report posted on websites or published in product guides) is sometimes available. The method for assessment of CF concentration quantifies IDF primarily from cellulose, capturing some lignin and a small amount of hemicellulose. This method does not measure a large portion of IDF nor any SDF; therefore, it is not an accurate measure of the totality of fiber in a food product. In contrast, IDF and most SDF are included in the measurement of TDF concentration; oligosaccharides are not detected by standard analysis for TDF and require additional methods for quantification.
Total dietary fiber concentration has been the standard measure for reporting fiber concentrations of human foods in the United States for approximately 30 years. An assay capable of measuring all compounds that behave physiologically as fiber has recently been developed. This assay may not be practical in all situations, given processing time and cost.

Modification of dietary fiber intake is often recommended by veterinarians to address conditions in nonhuman animals for which a change in fecal quality, gastrointestinal transit time, nutrient absorption, or satiety is desired. The physiologic effects of fiber are not uniform across all fiber types; thus, information regarding the amount and proportions of IDF and SDF not uniform across all fiber types; thus, information regarding the amount and proportions of IDF and SDF is relevant. In general, IDF increases bulk of fecal matter, whereas SDF contributes to softer feces with increased moisture content. Nutritional recommendations intended to change an animal’s fiber intake through diet modification can be difficult to formulate because the TDF concentration of commercial pet diets may not be accurately represented by the reported CF value.

We hypothesized that the TDF concentration of canine diets would not be accurately represented by either CF value and that the difference between CF and TDF concentrations would vary between dry and canned diets, as would proportions of IDF and SDF. The purpose of the study reported here was to analyze and compare measured CF and TDF concentrations in selected dry and canned nontherapeutic diets formulated for adult maintenance or all life stages of dogs and determine fiber composition (proportions of IDF and SDF) in those diets. An additional objective was to assess differences between measured and reported maximum CF concentrations of the diets.

Materials and Methods

Samples of commercially available dry and canned nontherapeutic canine diets were solicited from the faculty, students, and staff at the Veterinary Medical Teaching Hospital, School of Veterinary Medicine at the University of California-Davis and the outside community. Additional samples were purchased from local retail outlets to represent a variety of diets. Dry and canned nontherapeutic canine diets intended for adult maintenance or all life stages of dogs were included. Product name, type, lot number, ingredient list, GA data (if available), and expiration date were recorded. Reported maximum CF concentration (ie, the CF value reported among the label GA information) was also recorded. Samples without a GA or ingredient list as well as those that were from diets that had passed their expiration date or included a purified source of oligosaccharides were excluded from further assessment. Energy density, method of determination of energy density, and IDF concentration were solicited from manufacturers of all diets analyzed. For each diet, the contents of each dry diet sample were thoroughly mixed, and approximately 200 g was placed in a sealed, labeled plastic bag; cans (2 unopened cans weighing approx 354 g [12.5 oz] each) were labeled and submitted as purchased. Samples were submitted to a reference laboratory* and 1 sample from each diet was analyzed for CF, TDF, IDF, and moisture concentrations. Crude fiber concentration was determined via AOAC International official method 962.09. Total dietary fiber and IDF concentrations were determined via AOAC International official method 991.43; the SDF concentration was calculated as the difference between those 2 values. Moisture content was determined via AOAC International official method 930.15. For CF, TDF, and IDF measurements, the reference laboratory provided a measure of uncertainty for each sample:

\[
\text{Measure of uncertainty} = k \cdot \left( \text{SD of control sample} \times \frac{\text{test sample result}}{\text{mean of control sample}} \right)
\]

where the \( k \) factor is 95% confidence for reporting each result for a given test.

Median measure of uncertainty of CF concentration was 0.3% (range, 0.1% to 1.2%) for dry diets and 0.0% (range, 0.01% to 0.08%) for canned diets. Median measure of uncertainty of TDF and IDF concentrations was 0.8% (range, 0.5% to 2.0%) for dry diets and 0.1% (range, 0.1% to 0.3%) for canned diets.

Energy density was obtained from the manufacturer, or if not provided, it was calculated from the GA or TA data. When energy density was calculated, the following modified Atwater values were applied: 3.5 kcal/g for protein and NFE (an estimate of starch and sugar) and 8.5 kcal/g for fat. The measured concentrations of moisture and CF for that sample were used. In the case of diets for which ash concentration was not reported, a mean value calculated from ash concentration data from diets for which TA data were available was used (6.3% and 2.2% on an as-fed basis for dry and canned diets, respectively).

Statistical analysis—Statistical analysis was performed with a computer software program and Web-based applications. Most data were nonparametric, and all data are reported as median and range (for all diets \( n = 40 \), all dry diets \( 20 \), or all canned diets \( 20 \)) unless specified otherwise, for consistency. For nonparametric data, comparisons between assays and diet types were made via a Wilcoxon signed rank test for paired data and Mann-Whitney U test for unpaired data. For data with normal distribution (ie, measured values of SDF for dry and canned diets), comparisons were made via an unpaired \( t \) test. Values of \( P < 0.05 \) were considered significant. Total dietary fiber content on an as-fed, dry-matter, or ME basis was compared with energy density via linear regression analysis.

Results

Seventeen donated dry samples met inclusion criteria. No canned diets were donated. Three dry and 20 canned diets (15 loaf type and 5 meat-in-gravy type) were purchased. Dry diets represented 8 manufacturers, and canned diets represented 15 manufacturers.

In the present study, measured moisture content of each of the 20 dry diets did not exceed the GA moisture content. For the dry diets, the median difference between reported maximum moisture concentrations and the measured values was 3.4% on an as-fed basis (1.5% to 5.0% on an as-fed basis). The measured moisture content of 2 canned diets exceeded the reported maximum moisture concentration by 0.9% and 5.3%
For the canned diets, the median difference between reported maximum moisture concentrations and the measured values was 4.3% on an as-fed basis (–5.3% to 7.3% on an as-fed basis). There were significant differences between the reported maximum and the measured moisture concentration for both dry (P < 0.001) and canned diets (P < 0.01; Table 1).

For 1 dry diet, the measured CF concentration exceeded the reported maximum CF concentration by 0.2% on an as-fed basis (within allowed analytic variation). No canned diet had a measured CF concentration that exceeded the reported maximum CF concentration. The median difference between reported maximum CF concentration and measured CF concentration for dry and canned diets was 1.1% on an as-fed basis (–0.2% to 3.5% on an as-fed basis) and 1.1% on an as-fed basis (0.2% to 2.7% on an as-fed basis), which was significant (P < 0.001).

Energy density was reported by manufacturers for 16 dry diets and 19 canned diets. Of these, 2 dry diets and 14 canned diets had calculated values provided. For the remaining 14 of 16 dry and 5 of 19 canned diets, the method of determination of energy density was not specified; per Association of American Feed Control Officials regulations, this implies a measured value obtained via digestibility trials. None of the 4 dry and 1 canned diets with unreported energy density provided TA data; 1 of these dry diets had a reported maximum ash concentration, which was used to calculate ME for that sample. Energy density of the remaining samples (3 dry and 1 canned) was calculated via mean TA values for ash concentration, which was used to calculate ME for the remaining samples.

Median energy density was 3,852 kcal/kg on a dry-matter basis (2,824 to 4,208 kcal/kg on a dry-matter basis) for dry diets and 4,570 kcal/kg on a dry-matter basis (3,582 to 7,364 kcal/kg on a dry-matter basis) for canned diets; this difference was significant (P < 0.001). Energy density was not well correlated with TDF on an as-fed, dry-matter, or ME basis for either dry or canned diets (for all correlations, r² ≤ 0.4).

For all diets, TDF was composed of primarily IDF (median composition, 73.4% [range, 24.0% to 93.9%]), with the remainder being SDF (median composition 26.9% [range, 5.2% to 74.0%]; Table 2). For dry diets, IDF accounted for a median of 83.4% (range, 62.2% to 93.9%) of TDF and SDF accounted for a median of 16.2% (range, 5.2% to 37.8%) of TDF. For canned diets, IDF accounted for a median of 63.6% (range, 24.0% to 91.8%) of TDF and SDF accounted for a median of 36.4% (range, 8.2% to 74.0%) of TDF. Differences in proportions of IDF and SDF between dry and canned diets was significant (P < 0.001). Median TDF did not differ between loaf-type (6.1% on a dry-matter basis [range, 3.9% to 16.5% on a dry-matter basis]) and meat-in-gravity-type (11.5% on a dry-matter basis [range, 4.9% to 13.8% on a dry-matter basis]) canned diets. There was no difference in the composition of TDF (proportion of IDF and SDF) between canned diet types.

Measured CF represented a median of 23.8% (6.8% to 48.8%) of TDF for all diets (Figure 1). For dry diets, measured CF represented a median of 28.6% (18.6% to 48.8%) of IDF. For canned diets, measured CF represented a median of 18.0% (6.8% to 32.2%) of TDF. Differences between the proportion of TDF (on a dry-matter basis) detected in dry versus canned diets by the CF assay were significant (P < 0.001). Total dietary fiber and measured CF were correlated for both dry (r² = 0.87) and canned (r² = 0.79) diets on a dry-matter basis. Insoluble fiber was greater than measured CF (on a dry-matter basis) for all 40 samples analyzed. Measured CF represented a median of 33.5% (10.0% to 66.7%) of IDF for all diets. For dry diets, measured CF represented a median of 39.4% (20.7% to 59.6%) of IDF for all diets.

Table 1—Median (range) reported maximum and measured moisture (on an as-fed basis) and CF (on an as-fed basis) concentrations of commercially available, dry and canned, nontherapeutic canine diets.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Reported maximum moisture (%)</th>
<th>Measured moisture (%)</th>
<th>Reported maximum CF (%)</th>
<th>Measured CF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All diets (n = 40)</td>
<td>—</td>
<td>—</td>
<td>3.0* (1.0–15.0)</td>
<td>1.1* (0.1–11.5)</td>
</tr>
<tr>
<td>Dry diets (n = 20)</td>
<td>10.0† (9.0–12.0)</td>
<td>7.2† (5.6–8.5)</td>
<td>4.0† (3.0–15.0)</td>
<td>2.7† (1.3–11.5)</td>
</tr>
<tr>
<td>Canned diets (n = 20)</td>
<td>78.0§ (75.0–82.0)</td>
<td>74.1§ (69.4–81.3)</td>
<td>1.5§ (1.0–3.0)</td>
<td>0.3§ (0.1–0.8)</td>
</tr>
</tbody>
</table>

*†‡§||Within a row, median values with the same symbols are significantly (P < 0.001) different.
— = Not applicable.

Table 2—Median (range) CF and TDF including IDF and SDF fractions (determined on a dry-matter or ME basis) of commercially available, dry and canned nontherapeutic canine diets.

<table>
<thead>
<tr>
<th>Variable</th>
<th>CF</th>
<th>TDF</th>
<th>IDF</th>
<th>SDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry-matter basis (%)</td>
<td>All diets (n = 40)</td>
<td>1.9† (0.4–12.6)</td>
<td>8.4* (3.9–25.8)</td>
<td>6.2† (1.1–22.7)</td>
</tr>
<tr>
<td>Dry diets (n = 20)</td>
<td>2.9† (1.4–12.6)</td>
<td>10.3‡ (6.7–25.8)</td>
<td>8.4‡ (4.9–23.7)</td>
<td>1.6* (0.6–4.8)</td>
</tr>
<tr>
<td>Canned diets (n = 20)</td>
<td>1.1‡ (0.4–4.3)</td>
<td>6.5‡ (3.9–16.5)</td>
<td>4.3‡ (1.1–12.3)</td>
<td>2.5* (0.4–5.2)</td>
</tr>
<tr>
<td>ME basis (g/1,000 kcal)</td>
<td>All diets (n = 40)</td>
<td>5.6 (0.8–38.4)</td>
<td>21.9 (8.4–78.7)</td>
<td>16.6 (2.5–72.4)</td>
</tr>
<tr>
<td>Dry diets (n = 20)</td>
<td>7.7 (3.5–38.4)</td>
<td>27.0 (15.8–78.7)</td>
<td>21.6 (13.5–72.4)</td>
<td>4.3 (1.0–12.0)</td>
</tr>
<tr>
<td>Canned diets (n = 20)</td>
<td>2.3 (0.8–8.7)</td>
<td>13.2 (8.4–57.3)</td>
<td>9.0 (2.5–25.3)</td>
<td>5.4 (1.0–12.9)</td>
</tr>
</tbody>
</table>

*†‡§||Within a row, median values with the same symbols are significantly (P < 0.001) different.
* = Within a column, median values with the same superscript letters are significantly (P < 0.001) different.
to 53.2%) of IDF. For canned diets, measured CF represented a median of 27.9% (10.0% to 66.7%) of IDF. The proportion of IDF represented by measured CF was different between dry and canned diets (P < 0.05).

Discussion

To our knowledge, the present study was the first to find differences between reported maximum CF and measured CF with comparisons to TDF concentration and composition within the same group of samples of dry and canned nontherapeutic diets formulated for adult maintenance or all life stages of dogs. The goals of the study were to provide practitioners with clarification of 1 aspect of the GA and to demonstrate the inherent limitations. The results indicated that use of CF and the reporting of maximum rather than measured values contribute to an inaccurate representation of the amount and composition of dietary fiber in commercial canine diets.

Similar to results of another study,16 median measured moisture concentrations in both dry and canned diets were found to be significantly less than reported maximum values. This underscores the importance of comparing proportions of fiber and other constituents on a dry-matter basis or on an ME basis rather than on an as-fed basis. However, there are errors inherent in determination of ME, in particular when calculating energy density with data from the GA. Carbohydrate is reported as NFE, which is not a measured value but an estimate of the starch and sugar concentrations in a diet that is simply determined by difference. Any analytic inaccuracies or calculation errors in other constituents reported in the GA will affect the calculated calories contributed by carbohydrate, and in most cases, the total ME of the diet. For example, overreporting percentages of components given as maxima (moisture, CF, and ash) results in underestimation of calories contributed by carbohydrate and the total ME of the diet. Without measured values, the degree of discrepancy between actual and reported nutrient concentrations is unknown.

It is often assumed that high-fiber diets are lower in energy density and that CF or TDF may therefore be highly correlated with ME because fiber increases food volume but provides little to no calories. Kienzle et al18 proposed a method of estimating ME by use of measured fiber concentrations to adjust digestibility of the protein, fat, and NFE components of dry diets. Those researchers reported that ME determined in this way was correlated with gross energy as determined via bomb calorimetry but had increased accuracy when TDF rather than CF was used to determine NFE. In contrast, we found no correlation between CF or TDF and ME, despite similar CF and TDF concentrations for dry diets in both the present and the other study. The conflicting findings may in part be explained by a difference in experimental methods; Kienzle et al18 not only used different assays for the analysis of CF and TDF but also used measured concentrations of protein, fat, CF, ash, and moisture to determine ME, whereas in the present study, energy density provided by the manufacturer or calculated from the GA data was used.

Median measured concentrations of CF in dry diets in the present study were also similar to mean values reported by Hill et al.18 However, compared with the findings of Hill et al.,18 the median CF concentrations of canned diets were notably lower in the present study, and the resultant difference between measured and reported maximum values of CF was greater. The inclusion of cat diets in that other study18 may partly explain the greater variation reported. On the basis of the discrepancy between measured and reported CF, Hill et al.18 suggested the use of an adjustment factor (–0.7%) to more accurately determine the energy density of a diet from the GA data via modified Atwater factors. On the basis of the data for canine diets from the present study, factors of –1.3% for dry diets and –1.2% for canned diets or –1.9% for all diets could be proposed. Opitz et al13 also reported ranges of CF concentrations in dry and canned canine diets; these ranges overlapped but were generally lower than ranges determined in the present study.

Total dietary fiber concentration and composition were not significantly different between loaf-type and meat-in-gravy–type canned diets analyzed. Without a larger sample size, it is difficult to draw meaningful conclusions from these data. However, the difference in canned diet type could reasonably be expected to constitute real differences in amount and composition of TDF that may be reflected in physiologic response. More work is needed to determine whether this is an important consideration when selecting diets for the management of specific conditions.

Although reasonably correlated, measured CF concentration was a poor indicator of the measured concentration of TDF for all diets in the present study, with measured CF representing approximately 24% of TDF on a dry-matter basis. This discrepancy was greater for canned diets (approx 18% of TDF on a dry-matter basis) than for dry diets (29% of TDF on a dry-matter basis). Not surprisingly, CF was a somewhat better indicator of the amount of IDF than it was of the amount of TDF particularly for dry diets.
et al.17 found similar relationships between CF and TDF in dry dog and cat foods. In that study,17 when NFE was determined by difference on the basis of TDF rather than CF, the NFE concentration was similar to measured concentrations of starch in dry canine and feline diets. Those authors concluded that TDF was the best analysis for nonstarch polysaccharides.17 In their feeding trials,17 CF was determined by difference on the basis of TDF rather than CF, the authors acknowledged that CF does not represent all of the cellulose present in a particular diet.

Results of the present study have indicated that in the dry and canned nontherapeutic canine diets evaluated, CF was not representative of TDF and thus not a reliable indicator of a diet’s potential effects on intestinal health, fecal quality, gastrointestinal transit time, nutrient absorption, or satiety. Crude fiber concentration was slightly better correlated with TDF concentration in dry diets, compared with canned diets, and is a slightly better representation of IDF concentration than TDF concentration for all diets. The reported maximum values of CF from the GA were not representative of measured CF for dry or canned diets. Currently, a CF value is the only fiber index required on pet food labels by Association of American Feed Control Officials guidelines, yet results of the present and other studies have indicated that this is an inaccurate measure of dietary fiber. Veterinarians should realize that the CF value does not provide accurate information regarding the amount and type of fiber in a pet food and may not be indicative of a diet’s potential clinical effects. The physiologic effects of TDF, IDF, and SDF as well as specific mixed fiber types in diets have been evaluated in many studies. Although TDF measurement is a more useful method of assessing fiber content, only 1 manufacturer, which produced 2 of the 40 diets evaluated in the present study, provided TDF data upon request. Given that few manufacturers provide data on TDF, IDF, and SDF in diets, it is impossible for practitioners to apply research outcomes to their patients when the only information available is the CF value from the GA data reported on the label. The authors encourage more widespread determination and reporting of TDF, IDF, and SDF concentrations in commercially available pet diets to assist veterinarians in their efforts to provide meaningful nutritional management recommendations.

References

23. Association of American Feed Control Officials guidelines, yet results of the present study have indicated that in the dry and canned nontherapeutic canine diets evaluated, CF was not representative of TDF and thus not a reliable indicator of a diet’s potential effects on intestinal health, fecal quality, gastrointestinal transit time, nutrient absorption, or satiety. Crude fiber concentration was slightly better correlated with TDF concentration in dry diets, compared with canned diets, and is a slightly better representation of IDF concentration than TDF concentration for all diets. The reported maximum values of CF from the GA were not representative of measured CF for dry or canned diets. Currently, a CF value is the only fiber index required on pet food labels by Association of American Feed Control Officials guidelines, yet results of the present and other studies have indicated that this is an inaccurate measure of dietary fiber. Veterinarians should realize that the CF value does not provide accurate information regarding the amount and type of fiber in a pet food and may not be indicative of a diet’s potential clinical effects. The physiologic effects of TDF, IDF, and SDF as well as specific mixed fiber types in diets have been evaluated in many studies. Although TDF measurement is a more useful method of assessing fiber content, only 1 manufacturer, which produced 2 of the 40 diets evaluated in the present study, provided TDF data upon request. Given that few manufacturers provide data on TDF, IDF, and SDF in diets, it is impossible for practitioners to apply research outcomes to their patients when the only information available is the CF value from the GA data reported on the label. The authors encourage more widespread determination and reporting of TDF, IDF, and SDF concentrations in commercially available pet diets to assist veterinarians in their efforts to provide meaningful nutritional management recommendations.