Obesity in domestic cats is a major nutritional problem and has been associated with an increased incidence of diseases such as diabetes mellitus, urinary tract disorders, and dermatologic disorders.\(^1\) The cause of obesity is an imbalance between EI and energy expenditure, and neutering, low amounts of activity, and high-energy diets serve as common risk factors for the development of obesity in cats.\(^2\) Treatment of obesity in cats is possible with dietary management. Diets for weight reduction are usually formulated to restrict energy by decreasing the amount of fat and increasing the amount of low-digestibility fibers. For effective weight loss, these diets must be fed in restricted amounts or they must be sufficiently low in energy density to induce a decrease in voluntary EI.

Filling of the stomach results in activation of stretch receptors and mechanoreceptors, which leads to an inhibition of EI.\(^3\) Therefore, a common strategy for weight loss involves the use of diets with low energy density that contain adequate volume or bulk to induce filling of the stomach. Because of its low digestibility, dietary fiber is commonly used to decrease energy density of weight-loss diets. Although fiber is a key ingredient in diets marketed for management of obesity in cats, relatively little is known about the influence of fiber on EI in cats allowed ad libitum access to food. Two studies\(^4,5\) have revealed that the addition of dietary fiber to complete diets can cause a decrease in voluntary EI in cats allowed free-choice consumption of food. However, the decrease in EI in those studies\(^4,5\) was detected only when the diets contained at least 20% powdered cellulose (on an as-fed basis). This exceeds the amount of dietary fiber typically used in diets marketed for the management of obesity, and it is unlikely that the amount of fiber currently used in most diets for-

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**Objective**—To determine whether water content in a canned food diet induces decreases in voluntary energy intake (EI) or body weight (BW) in cats fed ad libitum.

**Animals**—16 sexually intact male domestic shorthair cats.

**Procedures**—Maintenance EI was determined for 2 months in 10 weight-stable cats consuming a control diet (typical colony diet). Cats were allocated into 2 groups of equal BW and fed a canned diet (with-water [WW] diet) or a freeze-dried version of the canned diet (low-water [LW] diet) twice daily. Diets were identical in nutrient profile on a dry-matter basis. Each dietary treatment period of the crossover experiment lasted 3 weeks, with a 3-week washout period between diets. Body composition measurements were determined by use of deuterium oxide at the end of each dietary treatment. Daily food intake was measured for determination of dry-matter intake and EI. In short-term preference tests, cats ate significantly more of the WW than the LW diet.

**Results**—EI was significantly decreased for the WW diet (mean ± SD, 1,053.0 ± 274.9 kJ/d), compared with EI for the LW diet (1,413.8 ± 345.8 kJ/d). Cats had a significant decrease in BW during consumption of the WW diet. Body composition was unaltered by diet. In short-term preference tests, cats ate significantly more of the WW than the LW diet.

**Conclusions and Clinical Relevance**—Bulk water in the WW diet stimulated decreases in EI and BW in cats. The impact of water content on energy density and food consumption may help promote weight loss in cats. (Am J Vet Res 2011;72:918–923)

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**Effect of water content in a canned food on voluntary food intake and body weight in cats**

Alfreda Wei, PhD; Andrea J. Fascetti, VMD, PhD; Cecilia Villaverde, BVSc, PhD; Raymond K. Wong, BS; Jon J. Ramsey, PhD

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mulated for cats would reduce energy densities enough to cause a decrease in EI in cats allowed ad libitum access to food.

In addition to fiber, water is also a dietary ingredient that lowers energy density. Water is the dietary component that has the greatest impact on energy density because it can add substantial weight to a diet without adding energy. Also, extremely high amounts of water can be included in a diet without causing a negative impact on palatability. For example, many canned foods formulated for cats contain approximately 80% water. Therefore, water may have a much greater impact on lowering energy density than fiber does. Also, in contrast to fiber, water does not negatively impact overall nutrient digestibility.

Few studies have been conducted in cats to examine the effect of dietary water content on EI or BW. Feeding diets (eg, canned foods) that contain high amounts of water may stimulate a reduction in voluntary EI. It has been reported that FI in cats is decreased when a high-moisture diet is fed. However, the diets used in that study differed in macronutrient composition, which makes it difficult to determine whether water or the macronutrient content was responsible for the changes in FI. Therefore, the purpose of the study reported here was to examine the effects of dietary water on EI, body composition, and BW in cats by feeding 2 diets with identical macronutrient compositions and caloric densities but different moisture contents to young sexually intact male cats. Our hypothesis was that ad libitum consumption of a canned food diet (high water content but low energy density) by cats over a 3-week period would result in a decrease in voluntary EI, BW, or both, compared with results for consumption of the equivalent canned food with a lower water content achieved via freeze-drying. The study was intended to provide information about the efficacy of the use of high-moisture diets for the prevention and treatment of obesity in cats.

Materials and Methods

Animals—Sixteen specific pathogen–free young sexually intact male domestic shorthair cats were included in 2 experiments in the study. All cats were housed separately in cages at the University of California-Davis. Room temperatures were maintained between 18°C and 24°C, with a light-to-dark cycle of 14 hours of light to 10 hours of darkness. Approval of experimental protocols was granted by the Institutional Animal Care and Use Committee of the University of California-Davis and complied with published guidelines.

Ten cats were included in an experiment to determine the effects of dietary water content in 2 diets on voluntary FI, EI, BW, and body composition; these same 10 cats were included in preliminary palatability trials during development of the test diets used in the study. These cats had ad libitum access to food and water. Cats were 8.8 ± 1.5 months old (median, 10.3 months) and had a mean ± SD BW of 4.28 ± 0.24 kg at the start of the study. Body condition scores (9-point scale) ranged from 4.5 to 6.0 (median, 5.0).

Six other specific pathogen–free sexually intact male domestic shorthair cats were included in a second experiment conducted to test preferences for consumption of the test diets. These 6 cats were 20.1 to 21.4 months old (median, 20.7 months) and had a mean ± SD BW of 5.13 ± 0.56 kg. These cats had never been fed the test diets prior to the experiment. These cats had ad libitum access to water, but only had access to food for 8 h/d.

Diets—Three diets were used for the study: a dry expanded cat food (control diet), a commercially available canned food (WW diet), and the same canned food but with the water removed by freeze-drying (LW diet). The control diet, a dry maintenance diet packaged exclusively for the University of California-Davis, was the diet typically fed to research cats at the facility, and it was routinely fed to the cats before the onset of the study. The nutrient composition of the control diet on a dry-matter basis was 38% protein, 17% fat, 32% carbohydrate, 4% crude fiber, and 9% ash. The calculated ME for the control diet was 16.19 kJ/g (3.87 kcal/g) on a dry-matter basis. This diet provided 34% of the energy from protein, 37% from fat, and 29% from carbohydrate and was formulated to meet the nutritional recommendations established by the Association of American Feed Control Officials for nutrient profiles of all life stages of cats. Production of the LW dry diet was accomplished by lyophilizing the canned diet to dryness and constant weight. The LW diet and WW diets contained identical nutrient compositions on a dry-matter basis (45% protein, 23% fat, 11% carbohydrate, 7% crude fiber, and 14% ash). The calculated ME was 16.40 kJ/g (3.92 kcal/g) on a dry-matter basis. The energy contribution to this diet for protein, fat, and carbohydrate was 41%, 49%, and 10%, respectively.

Freeze-dried versions of commercially available canned products of various textures and flavors enhanced with 10% beef-flavored stock or 10% water were fed to the 10 cats in preliminary palatability trials to determine the foods that they found most edible. Ultimately, the freeze-dried version of the canned food product enhanced with beef-flavored stock was deemed appropriate for use in the study because EI values were comparable with those for the control diet. For this reason, beef-flavored stock was then added to create the final product (LW diet) that contained approximately 10% moisture (the moisture content commonly found in commercial dry diets). Similarly, beef-flavored stock (10% of food content) was added to the canned product so that the LW and WW diets received the same treatment. The energy density of the LW and WW diets (on a dry-matter basis) was determined by use of bomb calorimetry analyses to be the same (4.70 kcal/g on a gross-energy basis). Proximate analysis values for the beef-flavored stock were obtained from the USDA nutrient database. These values were included in the nutrient composition calculations for the 3 diets (Appendix).

Effects of dietary water on FI, EI, BW, and body composition—For at least 6 months before the study, all 10 cats were fed the control diet. The health of each of the 10 cats was assessed on the basis of results of physical examination, biochemical analysis, and a CBC performed 2 weeks before the start of the study. Food intake was measured in the cats for 2 months before the
performed. The aqueous portion was extracted from the cats had access to fresh food for most of the day. Any food remaining in the cage at the time of the subsequent feeding was collected, dried (24 hours at 110°C), and weighed for determination of dry-matter intake. The FI for each cat was calculated by multiplying dry-matter FI by energy density. Measurement of body composition was performed at the end of each 3-week WW or LW diet treatment. Estimation of LBM and FBM was accomplished by use of a method for isotope dilution with D2O as described in another study.11 Food was withheld from cats for 16 hours and water was withheld from the cats for 2 hours before collection of a blood sample. A dose of D2O (0.4 g/kg) was administered SC to each cat, and the D2O was allowed to equilibrate for 3 hours.13 Blood samples were collected via jugular venipuncture into additive-free tubes.4 Tubes were allowed to clot for 30 minutes at 25°C; tubes then were centrifuged for 10 minutes at 2,817 × g. Serum was harvested and stored at −20°C until the extraction procedure was performed. The aqueous portion was extracted from the serum and analyzed for D2O content.13 Measurements for stable isotope dilution were obtained from serum without D2O and from D2O-enriched serum. The FBM was calculated by subtracting LBM from the total BW of each cat.

Dietary preference tests—Six cats were included in the experiment to determine dietary preferences. Cats were acclimated to the feeding format for 4 days. Cats had access to food for 8 h/d, after which the food was removed. Thus, food was withheld from the cats for 16 hours before the start of the dietary preference experiment. For the next 4 days, cats were offered 2 diets (WW and control diet) simultaneously in separate bowls and allowed 4 hours to eat. The diet placed in one of the bowls prior to the end of the 3-week period, the time was recorded and the food remaining in the other bowl was weighed. After the 4-hour test feeding period, cats were provided ad libitum access to the control diet for another 4 hours, after which food was removed until the following day. Fresh water was available to cats at all times.

After completion of the preference test for the WW and control diets, the procedure was repeated to compare the preference between the WW and control diets and between the LW and WW diets. There was a 4-day washout period between preference tests; cats were fed only the control diet during the washout period. Because a limited quantity of the LW diet was available, only 4 of the 6 cats were used for these last 2 preference tests and each of these last 2 preference tests were limited to 2 days, instead of the 4 days for the preference test of the WW and control diets.

Statistical analysis—All variables were tested for normality by use of a Shapiro-Wilk test, and results were reported as mean ± SD for each diet treatment. Daily FI and EI data were analyzed.1 Diet was included in the model as a classification factor. Comparisons between BW, LBM, and FBM for each treatment were made by use of a Student paired t test. For the preference test, treatments were compared by use of the Student paired t test. The P values reported were the result of 2-sided tests; values of P < 0.05 were considered significant for all analyses.

Results

EI—Mean ± SD baseline value for dry-matter FI during the 2-month prestudy period (ie, value for the control diet) was 82 ± 12 g/d. The FI for the WW diet (86 ± 21 g/d) did not differ significantly (P = 0.491) from the FI for the control diet. However, the FI for the WW diet (64 ± 17 g/d) was significantly lower than the FIs for the control (P = 0.017) or LW (P < 0.001) diets. Calculations based on these results revealed no significant (P = 0.400) differences in EI between the LW and control diets, whereas EI was significantly lower for the WW diet, compared with the EIs for the LW (P < 0.001) and control (P = 0.023) diets. When EI was adjusted on the basis of BW, the resulting value was significantly lower for the WW diet, compared with results for the LW (P < 0.001) and control (P = 0.012) diets. The EI adjusted on the basis of BW was not significantly (P = 0.567) different between the LW and control diets (Table 1).
BW and composition—Evaluation of BW measurements collected during body composition determinations revealed a significant decrease in BW when cats consumed the WW diet, compared with BW when cats consumed the LW (P = 0.006) or control (P = 0.030) diets. There was no significant (P = 0.986) difference in BW between cats when consuming the control or LW diets. No significant (P = 0.986) differences in BW of cats were detected between values determined during the 2 months before the study and at the end of the 3-week washout period. Values for LBM and FBM were not significantly (P > 0.100) altered by diet (Table 2).

Preference tests—The 6 cats ate significantly (P < 0.001) more of the WW diet (mean ± SD, 24 ± 6 g) than the control diet (2 ± 3 g) during the first 20 minutes after the bowls were placed in a cage. This corresponded to a mean EI of 398.6 ± 102.4 kJ (95.3 ± 24.5 kcal) for the WW diet and 26.1 ± 46.0 kJ (6.2 ± 11.0 kcal) for the control diet. After 240 minutes, cats consumed significantly (P = 0.005) more of the WW diet (mean ± SD, 46 ± 14 g) than the control diet (mean, 8 ± 8 g). The mean EI was 754.6 ± 227.9 kJ (180.2 ± 54.4 kcal) for the WW diet and 122.0 ± 133.3 kJ (29.2 ± 31.9 kcal) for the control diet; these values differed significantly (P = 0.004). Cats maintained a stable BW during the preference test between the WW and control diet. During the 240 minutes that testing was performed, cats consumed total EIs ranging from 41% to 92% of their daily energy requirements. Daily energy requirements were defined by the predicted maintenance energy requirements for lean cats published elsewhere.13

For the preference test between the LW and control diets, the mean ± SD EI determined for the 4 cats at 240 minutes on the first day was 139.0 ± 17.2 kJ (33.2 ± 4.1 kcal) and 579.3 ± 194.6 kJ (138.4 ± 46.5 kcal), respectively; these values differed significantly (P = 0.023). On the second day of that preference test, the EI determined for the 4 cats at 240 minutes did not differ significantly between the LW diet (218.1 ± 72.6 kJ [52.1 ± 17.4 kcal]) and control diet (411.7 ± 158.9 kJ [98.4 ± 38.0 kcal]). Total EIs after 240 minutes during this preference test contributed 44% to 69% of the daily energy requirements.

For the preference test between the LW and WW diets, mean ± SD EI determined for 4 cats at 20 minutes was significantly (P = 0.030) lower for the LW diet (46.6 ± 76.3 kJ [9.7 ± 18.2 kcal]) than the WW diet (473.7 ± 164.0 kJ [113.2 ± 39.2 kcal]). At 240 minutes, cats had consumed a mean total dry-matter intake of 8 ± 10 g (129.8 ± 158.0 kJ [31.0 ± 37.8 kcal]) for the WW diet and 48 ± 7 g (794.8 ± 122.8 kJ [190.0 ± 29.4 kcal]) for the WW diet; these values also differed significantly (P = 0.015). In this preference test, the combined EIs provided by both the LW and WW diets after 240 minutes ranged from 64% to 82% of the daily energy requirements of the cats.

Discussion

The purpose of the study reported here was to test the hypothesis that bulk water in canned foods fed to cats would cause a reduction in voluntary EI and promote weight loss. In humans, consumption of water-rich (low–energy dense) foods is associated with a decrease in voluntary EI and a subsequent decrease in BW.34 Few studies have been conducted to investigate the effect of dietary water on EI or BW in cats. Authors of 1 study15 conducted with diets that contained 9.1%, 27.8%, 54.5%, or 75.2% moisture concluded that dietary water content has no impact on overall EI in cats. However, the voluntary EI in cats consuming the control diet (9.1% water) was considerably less than the predicted maintenance energy requirements, thus raising concerns about the validity of the conclusions for that study.15 Furthermore, because moisture content in that study15 was modified by adding various amounts of water to ground dry cat food, it is possible that EIs were low because of the unpalatable texture and nature of the food.

In contrast, analysis of results from the present study revealed that dietary water in the WW diet induced a significant decrease in voluntary EI. Ad libitum consumption of the WW diet by cats for 3 weeks resulted in a small but significant weight loss, compared with results for the LW diet. To avoid variations in nutrient composition between treatments, the WW and LW diets used in the present study were from the same commercially available canned product, except that water was removed from the LW version via freeze drying. This ensured that the dry-matter nutrient composition of these 2 diets was identical. Acceptability of the WW diet by cats was determined by comparing EI with that of the control diet.

Table 1—Mean ± SD values (dry-matter basis) for FI and EI determined for 10 cats during consumption of control, WW, or LW diets.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control diet</th>
<th>WW diet</th>
<th>LW diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>FI (g/d)</td>
<td>82 ± 12*</td>
<td>64 ± 17*</td>
<td>86 ± 21*</td>
</tr>
<tr>
<td>EI (kJ/d)</td>
<td>1,321.8 ± 191.6*</td>
<td>1,053.0 ± 274.9*</td>
<td>1,413.8 ± 345.8*</td>
</tr>
<tr>
<td>EI (kcal/d)</td>
<td>315.9 ± 45.8*</td>
<td>251.7 ± 65.7*</td>
<td>327.9 ± 82.7*</td>
</tr>
<tr>
<td>FI (g/d)</td>
<td>70.2 ± 8.5*</td>
<td>55.6 ± 14.8*</td>
<td>73.3 ± 18.9*</td>
</tr>
</tbody>
</table>

*The control diet was a dry maintenance diet packaged exclusively for the University of California-Davis and was the diet typically fed to research cats at the facility; it was routinely fed to the cats before the onset of the experiment. The WW diet was a commercially available canned food,* and the LW diet was the same commercial canned food but with the water removed via freeze drying. Values for the control diet were determined for the 2-month period prior to the onset of the study. Cats were assigned to groups (5 cats/group) and fed the WW diet or LW diet for 3 weeks; all cats were then fed the control diet for a 3-week washout period, and then the alternate diet (WW or LW) was fed to each of the respective groups for 3 weeks.

Table 2—Mean ± SD values for BW and body composition variables determined for 10 cats during consumption of control, WW, or LW diets.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control diet</th>
<th>WW diet</th>
<th>LW diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW (kg)</td>
<td>4.5 ± 0.3*</td>
<td>4.4 ± 0.2*</td>
<td>4.5 ± 0.3*</td>
</tr>
<tr>
<td>LBM (kg)</td>
<td>3.9 ± 0.4</td>
<td>3.9 ± 0.4</td>
<td>3.9 ± 0.5</td>
</tr>
<tr>
<td>FBM (kg)</td>
<td>0.6 ± 0.1</td>
<td>0.5 ± 0.2</td>
<td>0.6 ± 0.3</td>
</tr>
<tr>
<td>LBM (% BW)</td>
<td>14 ± 2.7</td>
<td>12 ± 3.9</td>
<td>14 ± 6.3</td>
</tr>
</tbody>
</table>

See Table 1 for key.
The preference of each of the 6 cats for one diet over another when offered a choice of 2 diets was evident on a daily basis, even when preference tests were limited to 2 days. When provided with both the WW and control diets during the acclimation and testing periods, 3 of 6 cats approached the WW diet first and continued eating it for > 10 minutes. When testing the preference between the LW and WW diets, 3 of 4 cats approached and ate the WW diet as soon as the diets were placed in the cages (the other cat alternated between eating the LW and WW diet first). The general pattern observed during the first 3 minutes of feeding revealed that these cats preferred to eat the WW diet. This was also evident on the basis of the significant differences in FI and EI for the WW diet, compared with values for the control or LW diets. It is important to mention that a separate cohort of 6 diet-naive cats was used for the preference tests, and the possibility exists that the food preferences of those 6 cats may have differed from the preference of the first cohort of 10 cats. Nonetheless, the eating behaviors of the 6 cats during the preference tests suggested that they favored the WW diet over the LW and control diets. Thus, even though the cats in this study typically were fed only a dry diet, our findings support the recommendation by the National Research Council\(^1\) that cats will typically select a moist diet over a dry diet.

Results for the present study are in agreement with results of 2 other studies\(^6\)\(^–\)\(^16\) in which it was found that dietary water induced a decrease in voluntary EI. Investigators in one of those studies\(^6\) measured FI in cats allowed ad libitum access to commercial dry or canned diets for a period of 7 to 10 days, and they found that cats consumed less dry matter and fewer calories with the canned food, compared with results for the dry food. Investigators in the other study\(^16\) measured FI in cats consuming diets that contained 80% or 75% water. In that study,\(^16\) there was a significant decrease in EI in the cats consuming the diet with 80% water. Considered together, results of those studies support the hypothesis that diets containing a high amount of water may decrease EI and induce weight loss in cats. However, those studies also have 2 important limitations.

First, investigators in one of those studies\(^6\)\(^–\)\(^16\) used a meal feeding protocol, and the cats were only allowed access to food during two 1-hour periods each day. However, this does not adequately test the effect of dietary water on ad libitum EI in cats. Because of the time constraint for food access, the investigators may have detected larger changes in EI than would have been detected if the cats had continuous access to food. Second, the investigators in both of those studies\(^6\)\(^–\)\(^16\) used low- and high-moisture diets with different nutrient and ingredient compositions, which may have contributed to the differences they detected between treatment groups. The possible influence of specific nutrients on EI was avoided in the study reported here because the diets fed ad libitum to the cats were identical in ingredient and nutrient composition, except for the amount of water.

In the present study, which specifically involved 2 diets with identical caloric density (on a dry-matter basis), the decrease in EI when cats consumed the WW diet was accompanied by a decrease in BW of approximately 2%. It is possible that greater decreases in BW and changes in body composition may have been detected during a study with a longer duration. However, it is important to mention 2 limitations of the present study. First, the study involved the use of 2 diets that had equal nutrient compositions on a dry-matter basis, and the same results may not have been detected for moist and dry diets that differ in nutrient composition. In particular, canned diets can have a wide range of nutrient composition, and the water-induced decrease in EI may be blunted for canned diets with a high fat content. Second, the cats used in this study were young and not obese. Because obesity is more common in middle-aged or elderly cats, additional studies that include both lean and obese cats will be needed to determine the long-term influence of high-moisture diets on BW in cats.

Analysis of results from the present study indicated that water content in diets can induce a decrease in EI and BW in cats allowed ad libitum access to food with identical nutrient profiles. The use of these diets in designing feeding regimens that can be incorporated into weight-loss or obesity-prevention programs for cats has promise and warrants further investigations.

Appendix

Nutrient composition (on an as fed-basis) of control, WW, and LW diets fed to 10 cats.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control diet</th>
<th>WW diet†</th>
<th>LW diet †</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (%)</td>
<td>34</td>
<td>9</td>
<td>41</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>15</td>
<td>5</td>
<td>21</td>
</tr>
<tr>
<td>Crude fiber (%)</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>10</td>
<td>80</td>
<td>10</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>8</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Carbohydrate (%)</td>
<td>29</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>ME (kJ/g)</td>
<td>14.56</td>
<td>3.31</td>
<td>14.81</td>
</tr>
<tr>
<td>ME (kcal/g)</td>
<td>3.48</td>
<td>0.79</td>
<td>3.54</td>
</tr>
</tbody>
</table>

*The control diet was a dry maintenance diet packaged exclusively for the University of California-Davis and was the diet typically fed to research cats at the facility; it was routinely fed to the cats before the onset of the study. The WW diet was a commercially available canned food,* and the LW diet was the same commercial canned food but with the water removed via freeze drying. "Calculated with the addition of 10% beef-flavored stock."  

References