Energy Intake in Cats as Affected by Alterations in Diet Energy Density¹–³

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EXPANDED ABSTRACT

KEY WORDS: • intake • energy density • feline • regulation

Whether mammals have the ability to regulate total intake or intake of specific macronutrients is controversial. The definition of an animal that can regulate is one that will alter its ingestive behavior to maintain ("defend") adequate nutrient intake (1). Locusts, for example, alter the volume ingested to maintain intake of protein and carbohydrate in the face of dilution of foods with nondigestible bulk, a range of macronutrient combinations, or variation in the frequency of, and differing distances between macronutrients (1). Another striking example comes from the work of Theall et al. (2). In those experiments, rats ingested amounts of protein and carbohydrate within a tight range when challenged with foods containing 8 different macronutrient combinations. Rapid compensation for dietary dilution was also observed in many omnivorous and herbivorous species such as chickens (3), horses (4), cows (5), and humans (6).

Anecdotally, it was believed that cats were also able to regulate intake to maintain adequate macronutrient and energy intake. Small-scale studies suggested that cats consuming feed ad libitum will eventually reach a stable energy intake, but the weight at which this occurs is not predictable (7). This has important implications for feline health because the incidence of obesity is estimated at ~25% (8) and is predicted to rise. If cats merely regulate to the volume eaten, then a potential solution to obesity is the production of less energy-dense foods. If cats regulate to energy or macronutrient target, however, this approach will be unsuccessful. Previous studies were conducted over short periods and without adequate power, making it difficult to draw firm conclusions (9–12). The aim of the current study was to examine the effect of dietary dilution on intake in a large population of cats over an extended period of time.

MATERIALS AND METHODS

The study was of a randomized crossover design with 3 treatment arms. Cats were randomly assigned to 1 of 6 groups that were each exposed to all 3 diets in varying order for 10 wk. All cats were neutered and included 28 males and 20 females. The 3 wet diets were based on a standard commercial recipe, and energy density was manipulated via alterations in the ratio of meat to gravy (Table 1).

Cats were given with individual access to food for 1 h, twice daily 5 h apart. Cats were each allocated a total of 600 g/d, of which 400 g was offered in the morning session. Any food refused in the morning was reoffered with the 200-g allocation of food in the afternoon. At all other times, cats were housed with other cats in social rooms with free access to water. Intake was monitored daily and body weight was recorded weekly. Body composition was assessed at the beginning and end of each trial phase using dual energy X-ray absorptiometry (DXA; Hologic QDR-1000/W). Weight gains or losses >5% were highlighted; to minimize any potential adverse health effects associated with weight change, a decision was made whether to maintain an individual cat on the study or to remove it.

Data were assessed for normality of distribution by the Kolmogorov-Smirnov test. A paired sample t test was used to assess changes in body composition at the beginning and end of each trial phase. Changes in intake and body weight were assessed for significance using analysis of repeated measures. All statistical analyses were conducted using SPSS v 13.0. Differences were considered significant when \( P \leq 0.05 \). Data are presented as means ± SD, unless stated otherwise.

RESULTS

The least energy-dense diet (Diet A) was generally rejected, and the 16 cats that were exposed to this diet in the first phase were withdrawn from the study because of concerns associated with refusal of the diet. The remaining 32 cats were not subsequently exposed to this diet. A further 6 cats were also withdrawn from the study due to concerns over weight change.

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Data from the remaining 26 cats only were analyzed. As a result, this study is retrospectively powered at 70% with a significance level of \( P = 0.05 \) based on body weight.

When cats were fed Diet C, there was a significant reduction in energy intake within the first 5 d of exposure to the diet (\( P = 0.050; \) Fig. 1). A similar, if less pronounced change in energy intake was observed when cats first started to eat Diet B. However, when the mean weekly energy intake was compared, this did not vary significantly over time with either diet (Diet B, wk 1, 180 ± 48 kcal, wk 10, 190 ± 50.59 kcal, \( P = 0.899; \) Diet C, wk 1, 250 ± 73 kcal, wk 10, 232 ± 70 kcal, \( P = 0.939 \)). The mean energy intake, however, was significantly different between trial diets at all time points \( (P < 0.001) \) with cats consuming more calories when fed the higher energy density diet, Diet C. This was consistent on an individual cat basis with 22 of the 26 cats ingesting significantly more calories when fed Diet C \( (P = <0.01) \), whereas changes in energy density did not significantly alter energy intake in 4 cats.

Mean body weight did not differ over time when cats were fed either diet (Diet B, \( P = 0.100, \) Diet C, \( P = 0.899) \). Within this sample of cats, there was a wide range of body weights; thus, we reanalyzed the data according to body weight changes in individual cats (Fig. 2). All cats that ate Diet B maintained or lost weight, whereas cats that ate Diet C displayed a wider variety of behaviors, with some cats gaining weight as well as some losing or maintaining it. Only 4 cats maintained their body weight within 5\% of their starting weight irrespective of which diet they ate; these cats were the same 4 that did not differ in energy intake when fed Diets B or C.

The analysis of body composition by DXA showed that Diet C was associated with a significant decrease in grams of body fat (median: 152 g range: −84.3 to 405.0; \( P < 0.001 \)) and body fat percentage (median: 2.20\% range: −1.2 to 7.2\% \( P = 0.002 \)).

### DISCUSSION

As natural carnivores, the energy composition of a cat’s prey is relatively constant in both density and nutritional quality (7); therefore, cats have had no need to evolve the rapid adaptation mechanisms of other species, such as rats, that eat a variety of foodstuffs. The primary aim of this study was to examine the effect of energy dilution on intake in a large population of cats. Diet A was generally rejected, leading to a large number of cats being excluded from the study. The reasons for this are unclear. The refusal may be associated with the hedonics of the diet, for example its texture, or there may be a mechanism by which cats assess the suitability of a diet and reject it due to insufficient energy or macronutrient density. Despite the fact that several cats were removed from the study, we had sufficient numbers of cats to provide adequate statistical power to allow us to compare the effects of Diets B and C on food intake, body weight maintenance, and body composition.

For the remaining cats, energy intake did not differ over time with consumption of either Diet B or Diet C, but when cats ate Diet C, the more energy-dense food, they consumed more calories than when they were fed Diet B. Goggin et al. (7) previously showed in a small number of cats, in caged housing, that any compensation for reduced energy density requires a long period of time (80 d), and the weight at which a cat stabilizes is extremely variable. Other studies showed that adaptation to reduced energy density diets can take between 75 and 200 d (13) before cats return to eating a volume of food sufficient to maintain their energy requirements. The current study showed that over a 10-wk period, there was no adaptation to altered energy density in terms of either energy intake or body weight in all but 4 of the cats. Although these data agree with the findings of Goggin et al. (7), our data are significant in that they were obtained in cats that lived in an environment typical of that of apartment or indoor cats. Many cats throughout the world live solely indoors, and it is in this population of cats that the incidence of obesity is particularly high.

The data obtained in this study show that cats ate approximately the same amount of food (g/kg body weight) irrespective of which diet they were given. This resulted in a higher energy intake when the cats ate Diet C, the more energy dense of the 2 diets. Some cats gained weight, which can be explained by the availability of excess energy. Nine cats however, maintained their body weight within 5\% of their starting weight while consuming Diet C. Four of these cats were
able to maintain their body weight irrespective of which diet they ate; the remaining 5 cats lost weight while consuming the energy-diluted diet, Diet B. All cats either maintained or lost weight while consuming Diet B, despite excess food being available. It is possible that the cats that lost weight were not able to increase their energy intake due to limits in gut distension. All cats were meal fed, which may have limited the opportunity for some cats to eat throughout the day to reach their energy requirements and therefore maintain body weight.

The changes in body composition did not reflect the changes in body weight. Nine of the 26 cats gained body fat, measured in grams, when fed the less energy-dense diet, Diet B, whereas none of the cats gained body weight while consuming this diet. This reflects a disproportionate loss of lean body mass and highlights the importance of including body composition measurements in future studies. The aim of any weight loss program should be to maximize loss of fat while minimizing loss of lean tissue. Preventing the loss of lean tissue minimizes weight loss-induced suppression of metabolic rate (14) and prevents weight regain.

In all but a minority of animals in this study, cats appeared unable to self-regulate their energy intake when fed commercial wet diets. The data suggest, however, that stomach fill may play an important role in constraining food intake in cats that are meal fed. For overweight cats, feeding an energy-dilute wet diet in 2 discrete hourly meals may be one way of either minimizing further weight gain or promoting slow weight loss. The diet, however, should be suitably balanced to ensure that the cat receives the optimum level of essential nutrients, and that the

weight loss results from fat loss and is not so rapid that complications arise.

**LITERATURE CITED**