Increasing volume of food by incorporating air reduces energy intake*

Samuel Serisier¹, Anthony Pizzagalli¹, Lucie Leclerc¹,², Alexandre Feugier¹, Patrick Nguyen², Vincent Biourge¹ and Alexander J. German³†

¹Royal Canin Research Center, Aimargues, France
²Nutrition and Endocrinology Unit, Oniris, National College of Veterinary Medicine, Food science and Engineering, France
³Department of Obesity and Endocrinology, Institute of Ageing and Chronic Disease, University of Liverpool, Liverpool, UK

(Received 11 November 2013 – Final revision received 11 March 2014 – Accepted 21 March 2014)

Abstract
Major challenges with weight management using weight-loss diets include hunger and rapid consumption of food, both of which lead to poor owner compliance. The aim of the present study was to determine the effect of increasing volume, by incorporating air, into dry expanded food, on satiety in dogs. Three studies have been performed. The first study aimed to measure the effect of volume of food on meal duration in dogs fed at their maintenance energy requirement. The purpose of the second study was to determine the effect of volume of food on satiety. The aim of the third study was to compare the satiety effect of the test diet with a maintenance dry diet commonly used in adult dogs. Throughout the studies, faecal score remained optimal. As volume of diet increased, the duration of food intake significantly increased (P < 0.001) and energy intake significantly decreased (P = 0.012). The present study has demonstrated that incorporating air into food to increase the volume of diet induces a satiety effect, independent of macronutrient profile, possibly by slowing food intake. Consequently, incorporating air into food might be a useful strategy for weight management in companion animals.

Key words: Weight management: Satiety: Volume of food: Canine nutrition

Overweight and obesity are common in dogs and cats, and predispose them to a variety of diseases and decreased longevity(¹). Weight-loss programmes are successful in experimental trials²,³, but do not perform as well in practice⁴,⁵. A major hurdle is that energy restriction causes hunger, which leads to increased begging behaviour. This puts increased strain on the owner-animal bond, which can affect owner compliance with the weight-loss programme. Developing strategies to improve satiety would greatly assist in case management.

Evidence from human studies suggests that some foods may be more effective than others in reducing hunger, probably because of the influence of macronutrients in the diet⁶. In pets, foods with increased fibre⁷ or water⁸ content are the most satiating. However, both have limitations; excessive dietary fibre can adversely affect digestibility⁹, while water can affect faecal consistency especially in breeds with lower digestive tolerance¹⁰.

Increasing meal volume can also increase satiety, and thereby decrease energy intake, and strategies used successfully in human subjects include incorporating air into liquid yogurt¹¹ and snacks¹². However, such an approach has not hitherto been used in companion animals. Therefore, the aim of the present study was to determine the effect of incorporating air into dry expanded food on ad libitum food intake in dogs.

Materials and methods

Ethical approval

Housing and management protocols adhered to European regulatory rules for animal welfare, while all experimental
protocols complied with European Union guidelines on animal welfare and were approved by the Royal Canin Committee for Animal Ethics and Welfare.

Diets

The test diet was a complete, dry, expanded diet, designed to fulfil maintenance energy requirements in dogs (Table 1). The density of this diet was low (125 g/l) compared with standard maintenance dry diets used in adult dogs (350–400 g/l). For study 2, the satiety effect of the test diet was compared with a control diet with exactly the same formula but a greater density (290 g/l, 4396 kJ/l; Table 1). In the study 3, the satiety effect of the test diet was compared with a maintenance dry diet commonly used in adult dogs (400 g/l, 6479 kJ/l; Table 1).

Study 1: effect of food volume on meal duration

The aim of this study was to determine the effect of altering meal volume, without changing meal energy intake, on meal duration in dogs fed at maintenance energy requirement, and to determine whether differences existed among breeds. Fifteen adult neutered female dogs of various breeds (e.g. Labrador retriever, Fox terrier, Beagle, Golden retriever, Dachshund, Brittany spaniel, German Shepherd dog and Cocker spaniel) were used. The median age was 11.2 (3.2–13.3) years, median body weight (BW) was 17.7 (7.1–42.8) kg and all dogs were in ideal body condition (i.e. body condition score 5/9). The energy requirement to maintain optimal BW had been empirically determined for each dog prior to the study, and the group median was 431 (280–769) kJ/kg0.75/d. To avoid weight gain during the study, the maximum food fed to each dog was its individual daily energy requirement. Daily requirements were divided into two meals of equal size. In order to create four diets with different volumetric energy densities, the dogs’ usual diet and the test diet were mixed in different proportions; the final energy densities of the resulting diets were 3344 kJ/l (diet 1), 2855 kJ/l (diet 2), 2370 kJ/l (diet 3) and 1881 kJ/l (diet 4), respectively. Dogs were successively fed the four diets at their individual maintenance energy requirement (in two meals per d) for five consecutive days, with the order of diets determined by Latin square. Energy intake, duration of meals and BW, were recorded as well as faecal score according to the five-point scale previously described[14]. Energy intake was measured by weighing the bowl before and after a meal to determine the amount of food eaten. The energy consumed was then calculated by multiplying the energy content of the food by the amount consumed.

Study 2: satiety effect of food volume

The aim of this study was to determine the effect of altering volumetric energy density while maintaining macronutrient profile, on satiety in dogs. Ten adult beagle dogs (three intact males, seven neutered females) were used. Median age was 5.6 (2.8–8.2) years, median BW was 11.82 (7.96–14.02) kg, and all were in ideal body condition (5/9) or slightly overweight (6/9). Two diets, with the same macronutrient profile but different volume, were compared using a cross-over design to assess the effect of volume on energy intake. The test diet was compared with an identical diet with higher density (290 g/l, 15162 kJ/kg, 4397 kJ/l; Table 1). Food intake was measured when diets were fed at hourly intervals, as previously described[7]. Briefly, individual dogs were offered 502 kJ/kg for 15 min at 08:30 (first meal) and at 09:30 (second meal) and then offered 1005 kJ/kg for 30 min at both 10:30 (third meal) and 11:45 (fourth meal). Each diet was tested three times on three non-consecutive days, and the energy intake at each meal recorded.

Study 3: satiety effect of test diet compared with standard adult canine maintenance diet

The aim of this study was to compare the satiety effect of the test diet compared with a maintenance dry diet commonly used in adult dogs and which density was higher than the control diet used in the study 2. The test diet (125 g/l, 15162 kJ/kg, 1895 kJ/l) was compared with a standard adult canine maintenance dry diet (Medium adult dry, Royal Canin; 400 g/l, 16297 kJ/kg, 6485 kJ/l; Table 1) using a cross-over design. Ten adult beagle dogs (two intact males,
eight neutered females) were used. Median age was 5.7 (5.0–11.6) years, median BW was 10.4 (8.8–15.9) kg, and all were in ideal body condition (5/9) or slightly overweight (6/9). Four meals were offered at hourly intervals, in the same manner as for study 2, and the energy intake at each meal was recorded by weighing bowl before and after meals.

**Statistical analysis**

All data were analysed using the Statistical Analysis Systems Institute package (SAS version 8; SAS Institute Inc.), and the level of statistical significance set at \( P < 0.05 \), for two-sided analyses. Data were analysed by two-way non-parametric or parametric (as appropriate) ANOVA using the mixed procedure of SAS. Diet, week and their interaction were included as fixed effects and the dog was included as a random term. Results were expressed as median (range) or means with their standard errors as appropriate.

**Results**

**Study 1: effect of food volume on meal duration**

When dogs were fed their normal diet, median meal duration determined over five consecutive days was 85 (29–430) s. There was no effect of diet on energy intake (\( P = 0.513 \)) but, as greater proportions of the test diet were fed, meal duration increased significantly (\( P < 0.001 \)). In this respect, food intake for diets 1, 2, 3 and 4 was 431 (281–775), 423 (226–762), 427 (272–775) and 423 (285–695) kJ/kg \( ^{0.75} \) respectively, while meal duration was 171 (55–900), 185 (77–900), 268 (80–900) and 374 (136–900) s, respectively. BW did not change during the course of the study (\( -3 \) to +7) %; \( P = 0.111 \), faecal score remained optimal throughout, and there were no differences on the different diets.

**Study 2: satiety effect of food volume**

None of the dogs ate all of the food offered during the study. Energy intake was lower by 19 (40 to +4) % with the test diet compared with control diet (\( P = 0.012 \)) (Table 2). This effect remained whatever the week of the test (\( P = 0.605 \)), and there was no diet–week interaction (\( P = 0.438 \)). BW of dogs did not change significantly during the 2 weeks of the study (\( -0.7 \% \) to +4.1 %, \( P = 0.614 \)).

**Study 3: satiety effect of test diet compared with a standard adult canine maintenance diet**

None of the dogs ate all of the food offered. Over the course of the study, a decrease in energy intake was noted with all diets, and this started at the second meal (\( P < 0.001 \)); energy intake was lower by 31 (–17 to –41) % with the test diet compared with the standard canine maintenance dry diet (Table 2). This effect remained whatever the week of the test (\( P = 0.214 \)), and there was no diet–week interaction (\( P = 0.472 \)). BW of dogs increased significantly when they fed ad libitum the standard maintenance dry diet during 1 week (5 (–2 to 7) %; \( P = 0.004 \)), while their BW did not change when they fed ad libitum the test diet during 1 week (0 (–9 to 3) %; \( P = 0.418 \)). Faecal score remained optimal throughout the study, whatever the diet.

**Discussion**

The present study has demonstrated that using air to increase the volume of dry dog food decreases energy intake and increases meal duration in ad-libitum-fed dog. These results confirm and extend findings from previous studies in human subjects demonstrating that using air to increase food volume and decrease energy density, can improve satiety \(^{11,12}\). Other strategies for decreasing the mass:energy ratio of a diet include adding water or dietary fibre, and both are also known to enhance satiety \(^{7,8}\). However, negative effects can be seen with both strategies, including the possibility of soft faeces when using wet food, most notably in breeds at risk of poor stool quality such as German Shorthair Pointers and German Shepherd dogs \(^{10}\). In contrast,

**Table 2. Energy intake in kJ/kg\(^{0.75}\) for each meal and the total energy intake for the study 2 and study 3**

<table>
<thead>
<tr>
<th>Study 2</th>
<th>Study 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test diet</strong></td>
<td><strong>Control diet</strong></td>
</tr>
<tr>
<td>First meal</td>
<td>Second meal</td>
</tr>
<tr>
<td>Mean</td>
<td>400</td>
</tr>
<tr>
<td>SEM</td>
<td>39</td>
</tr>
</tbody>
</table>

\( ^{1} P < 0.05; ^{2} P < 0.01; ^{3} P < 0.001 \) v. corresponding meal of control diet for study 2 and standard maintenance diet for study 3.

Study 2: total energy intake was lower with the test diet compared to control diet (\( P = 0.012 \)). This effect remained whatever the week of the test (\( P = 0.605 \)), and there was no diet–week interaction (\( P = 0.438 \)). Study 3: energy intake was lower with the test diet compared with the standard canine maintenance dry diet (\( P < 0.001 \)). This effect remained whatever the week of the test (\( P = 0.214 \)), and there was no diet–week interaction (\( P = 0.472 \)).
facial quality was not affected when dogs consumed the volume-expanded dry diet of the present study.

The exact reason for this effect is not clear. One possibility is that the increase in meal volume results in a longer meal duration, allowing a greater time for the release and effect of gastrointestinal satiety hormones. In previous studies, in obese adolescents, retarding to slow food intake had a profound effect on release of satiety hormones including a decrease in secretion of the orexigenic hormone ghrelin, and an increase in secretion of peptide YY which can decrease appetite\(^{15}\). The present study did not aim to determine the physiological basis for such changes, and further studies, for instance measuring ‘satiety hormones’ would now be required to produce a better understanding.

The present studies were designed to assess effects on food intake when the energy balance of dogs was either neutral (study 1) or positive (study 2 and 3) energy balance. The beneficial effect seen on satiety could be of use as a strategy for prevention of weight gain in dogs. Moreover, incorporating air into pet food, to increase volume of food, could have a beneficial psychological impact on owners without providing more energy to companion animals. Indeed, many owners use food as a primary means of showing love to their dogs, and readily feed more when signs of hunger are evident\(^{15}\). A diet that enables owners to feed more food, volumewise, without feeding more energy would, thus, be of great benefit. Nonetheless, given that the studies performed were only short-term in nature, it is possible that the effect would not be maintained over time, and further studies would be required to examine the duration of effect. In addition to preventing weight gain, the strategy could help with compliance of obese dogs on weight management regimes. Inadequate compliance of owners is a major problem in the prevention and treatment of pet obesity. Indeed, the owners of obese dogs spend more than twice as long watching them eat\(^{16}\). The perception of a satisfied dog, even when on a weight management regimen could have a beneficial psychological impact on owners certainly help to ensure that owners persist with a weight-loss programme. Inadequate compliance of owners to produce a better understanding. A further limitation was the studies were short in duration and, as a result, longer-term satiety effects were not assessed. Furthermore, while increasing diet volume did slow food intake, the effect was relatively minor overall. It is unclear as to what effect this difference would have in the voluntary food intake of pet dogs, with different owners, with variable feeding strategies. As a result, additional studies are now needed, which use a larger and more diverse population of (ideally pet) dogs, monitored over longer periods.

In conclusion, results from the present study indicate that incorporating air into food provides a strategy to reduce energy intake in dogs and, consequently, could be a useful strategy for weight management in pets. A prospective clinical trial is now required to determine the effect on satiety in obese dogs during a weight-loss programme.

Acknowledgements

The authors are grateful to Samuel Ninet for technical assistance and Karine De Melo Santos for the study 3. The authors wish to thank all care-givers for participating in the study. This study was funded by Royal Canin. Royal Canin manufactured the diets used in the present study. S. S., A. P., A. F. and V. B. were employed by Royal Canin. L. L. and A. J. G. were financially supported by Royal Canin. All authors were involved in the study design, interpretation of data and in the decision to submit the manuscript for publication. In addition, S. S. supervised the study and produced the first draft of the manuscript, A. P. designed and produced the test diet, L. L. performed the animal study, A. F. conducted the statistical analysis, P. N. is the director of the facilities in which the study was performed, V. B. assisted in supervising the study and is the scientific director of Royal Canin, A. J. G. assisted in the initial draft of the manuscript and supervised paper writing.

This paper was published as part of the WALTHAM International Nutritional Sciences Symposium Proceedings 2013, publication of which was supported by an unrestricted educational grant from Mars Incorporated. The papers included in these proceedings were invited by the Guest Editor and have undergone the standard journal formal review process. They may be cited.

References

of lean tissue mass correlates with overall percentage of weight lost. 

formulation to assess the satiating effect of food. *Appetite* **29**, 
291–304.

diet designed for weight loss improves satiety in dogs. *J Vet Intern 

increasing water content to reduce the energy density of the diet on 
body mass changes following caloric restriction in domestic cats. 
*J Anim Physiol Anim Nutr (Berl)* **95**, 399–408.


effects on fecal quality of mixed diets with various hydrocolloid 
1679S–1681S.

361–368.


Academies Press.

and body size on gastrointestinal transit time of radiopaque markers 

behavior reduces body weight and improves gastrointestinal hor-
monal secretion in obese adolescents. *J Clin Endocrinol Metab* **97**, 
E193–E201.

feeding behavior and the human–animal relationship in owners of 